CO_2 emission reduction in transport

Confronting medium-term and long-term options

Policy Studies

Netherlands Environmental Assessment Agency

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Confronting medium-term and long-term options for achieving climate targets in the Netherlands

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The project is registered at the Energy research Centre of the Netherlands
under project number 7.7913.

Netherlands Environmental Assessment Agency

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PBL publication number 500076009
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This publication can be downloaded from our website: www.pbl.nl/en. A hard copy may be ordered from: reports@pbl.nl, citing the PBL publication number.

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Abstract

Long term climate goals call for immediate investment in new transport technology

To meet long-term climate targets, developed countries should reduce greenhouse gas emissions with 65 to 95% compared to 2000 levels. If the transport sector should match these reductions three crucial conditions need to be fulfilled: (1) substantial changes in travel behaviour, travel demand and public acceptance, (2) availability of zero-carbon or low-carbon fuels, (3) availability of advanced vehicle technology. The measures that are currently available for the period until 2020 do not have sufficient potential to meet the long-term climate targets. To meet these goals, there is a need for parallel investments in 'new' technologies (electricity, hydrogen) which, in the future, could be decarbonised to a large extent. Since these new technologies have long lead and implementation times, a policy strategy should be developed today, which ensures that experience is gained and cost reductions are induced. A similar conclusion can be drawn for the Dutch climate policy programme *Schoon en Zuinig*: Most transport measures in the Dutch policy programme that contribute substantially to the emission reduction target for 2020 create little incentive for the development of vehicle technology and low-carbon fuels, which are needed in the long term.

Keywords: transport, CO_2, climate, options

Contents

Summary

To meet long-term climate targets, developed countries should reduce greenhouse gas emission with 65 to 95% compared to 2000 levels. The European Commission and some individual Member States, including the Netherlands, have set intermediate climate targets for 2020 in an attempt to bring long-term targets closer.

The main question of this report is whether current Dutch climate targets for the transport sector, and the measures currently (considered to be) implemented to reach 2020 targets will indeed help to bring long-term targets within reach.

To asses this, a review was carried out of the emission reduction potential in the transport sector, by the year 2050. First, the crucial conditions for reaching a (near) zero CO_2 emission transport sector were identified. Next, the transport measures as adopted by the Dutch Government to reach certain targets by 2020 were subjected to a qualitative assessment, to identify whether current transport measures provide synergy between medium-term and long-term targets. The criteria used were effectiveness, cost-effectiveness, flexibility, technological innovation, secondary benefits, and sustainability issues.

This report has based its analysis on the assumption that the transport sector should reduce its emissions with 65 to 95%[1] compared to 2000, the same as in other sectors. The question of whether equal burden sharing over sectors is the most efficient strategy for achieving long-term climate targets, is not answered in this report. The report does elaborate on various cost calculation methods that can result in very different targets for different sectors.

The report considers the transport sector as a whole. It should be noted, however, that most information presented here focuses on road transport and light-duty transport (passenger cars) in particular.

1 The global CO_2 reduction targets for 2050, required to keep the temperature increase below two degrees as advised by Stern (2006) and IPCC(2008), respectively, results in emission reductions of 65 -95% for the transport sector; taking into account the expected doubling in transport volume (King 2007), and assuming an equal share of emission reductions over all sectors.

Main conclusions

Long term (2050)

- The transport sector, like other sectors, faces the major challenge of meeting long-term targets for reducing emissions by 65 to 95%, compared to 2000 levels, especially since the transport volume is expected to double between 2000 and 2050.
- Further incremental improvements of conventional Internal Combustion Engine (ICE) technologies could result in maximum efficiency gains of about 50%, and could only lead to a stabilisation of transport emissions. This makes clear that a long-term emission reduction target of 65 to 95% cannot be achieved merely by improving conventional technology. Reaching the long term target with a substantial share of conventional technology would thus require a substantial reduction of transport volume.
- However, several options are available to decarbonise transport to a large extent. There are three crucial conditions for achieving CO_2 reductions of 65 to 95% in the transport sector:
  1. Substantial changes in travel behaviour, travel demand and public acceptance;
  2. Availability of zero-carbon or low-carbon fuels;
  3. Availability of advanced vehicle technology.
- The first criterion is difficult to control, but nonetheless crucial for the success of climate policy. Much attention in the debate on mitigation of climate change in the transport sector is given to the technical potential of future technology. The way this potential could be realised highly depends on public acceptance and the willingness of people to alter their mobility behaviour.
- The long-term emission reduction potential for the Netherlands also highly depends on successful international cooperation and agreement, and on the resulting effectiveness of European climate policies, as these will be essential for the introduction of advanced vehicle technologies and low-carbon fuels.
- For passenger car transport, both electricity and hydrogen in combination with Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs) have the potential for achieving a long-term CO_2 reduction target in the range of 65 to 95%. Only when combinations of low-carbon energy carriers and advanced vehicle technology become available at a large scale, this target could be met. Therefore, policymakers should adopt an integrated approach for the energy and transport sectors, aimed at facilitating

a smooth transition towards the production of both advanced vehicles and a low-carbon energy carrier.

- Both the electricity and hydrogen pathway for passenger car transport are characterised by long development and implementation trajectories. No 'winning' technology can be identified with certainty at this time, although the classic chicken-and-egg problem associated with the availability of the fuel infrastructure seems much more prominent for the hydrogen route. Decarbonisation of both technologies relies heavily on Carbon Capture and Storage (CCS) and/or massive implementation of renewable energy sources, especially wind.
- The large-scale utilisation of electricity and hydrogen in transport could be complemented by second generation biofuels, applied in vehicles with advanced internal combustion engines. The total amount of biofuels available will be limited, however. For this reason, biofuels should preferably be applied in subsectors or niches where they could not be (easily) substituted with electricity or hydrogen; for example, in long-haul trucking and shipping.
- The technical potential for emission reduction in road freight transport, aviation and shipping, is smaller than in passenger car transport. To achieve emission reductions of 65 to 95%, these transport modes depend stronger on biofuels and changes in mobility demand and behaviour (improved logistics in freight transport and reduced air travel). Relatively little information is available for these modes and additional research is recommended.

Short term (2020)

- There is limited additional technical potential, on top of the measures proposed in the Dutch policy programme *Schoon en Zuinig*, to reduce transport emissions. This is partly explained by the fact that replacing vehicle stocks takes time, thereby limiting the pace at which clean technologies can penetrate the vehicle fleet. Furthermore, it is observed that the additional reduction potential relates to mobility behaviour or vehicle choice, imposing additional barriers with respect to public and political acceptance.
- About 70% of the Dutch 2020 CO_2 reduction target for transport requires measures that depend on successful international cooperation and agreement (e.g. sustainability criteria for biofuels, and CO_2 emission limits for vehicles). Meeting Dutch targets for 2020, thus, highly depends on the success of European climate policy. This stresses the need for a strong presence and substantive contributions by Dutch policymakers in Brussels.
- The Dutch Government considers a 10 to 20% share of biofuels by 2020. If supported by policies to assure sustainability criteria, the Netherlands could obtain the 10 to 20% share by imports and national production. However, with a global view, it is questionable whether a short term high share of biofuels in transport is attainable under sustainability criteria currently considered. In addition, adopting large shares of biofuels before 2020 may hold the risk of lock-in, particularly for biodiesel, where the production process greatly differs between first and second generation fuels. Advanced biofuels will not enter the market in large quantities before 2020. These fuels have a better potential for reducing CO_2 emissions and meeting sustainability criteria. The long-term robustness of CNG can also be questioned in light of the limited climate benefits, unless CNG is gradually replaced by green gas.

Synergy 2020 and 2050 policies

- To achieve the challenging long-term climate targets for transport, very different measures are needed in addition to those currently included in the Dutch policy programme. The reason for this is that most measures that contribute substantially to the emission reduction target for 2020 create little incentive for the development of vehicle technology and low-carbon fuels, which are needed in the long term. For this purpose, an innovation programme is included in the policy programme, investigating the possibilities for sustainable transport and alternative fuels beyond 2020. This report recommends that additional research is carried out to analyse the effectiveness of the Dutch innovation strategy. This effectiveness is crucial for the success of long-term mitigation strategies.
- Given the ambitious emission reduction targets, and the limited potential of short-term measures, it is clear that these measures should be complemented by parallel investments in 'new' technologies (electricity, hydrogen) which, in the future, could be decarbonised to a large extent. Since these new technologies have long lead and implementation times, a policy strategy should be developed today, which ensures that experience is gained and cost reductions are induced. This strategy should allow for these new technologies to reach their full implementation in time. At a limited total budget, overinvestment in incremental improvement of conventional technologies may hinder investments in, and success of long-term, essential alternatives.
- CO_2 emission legislation for passenger cars and vans is a measure that *does* create a certain synergy with long-term targets. The synergy may come from increased shares of hybrids and plug-in hybrid vehicles, which require similar battery technology as future Battery Electric Vehicles. Nevertheless, it is important to consider the inclusion of stronger incentives for the development of more disruptive innovative clean technologies, which are essential for reaching the ambitious, long-term targets.
- Reduction in transport demand (through, for example, road pricing and mobility management) is robust and no-regret, since it contributes to both the short-term and the long-term climate targets. Over the last decades, however, transport demand has been closely linked to economic and demographic growth, and the success of policies that aim to reduce mobility has not been equivocal.
- Some technical measures that can be applied in current vehicle technology, as well as future vehicle technologies, are also robust or no-regret. Examples are energy efficient tyres, weight reduction, aerodynamics, tyre pressure indicators, and energy-efficient air conditioners.

Purpose of the report

This report is meant to contribute to the debate between policymakers and research groups on the steps that need to be taken to meet long-term climate targets. This reports shows that the current focus on intermediate targets for the year 2020 needs to be extended to include the long-term targets.

Although measures taken for the period up to 2020 may bring long-term emission targets closer, there may be trade-offs when measures which are implemented now will prove to be insufficient to meet long-term targets. Although these trade-offs are difficult to determine, it is important to address them, since ignoring them could hinder a smooth transition to low-carbon energy consumption.

A confrontation of medium and long term options to meet climate goals can also be found in the report '*Schoon en Zuinig* in breder perspectief' (Clean and Efficient in a broader perspective) (PBL, 2009). That report focuses on the Netherlands as a whole, including all sectors, whereas this report gives a more in depth analysis for the transport sector.

Introduction

1

Transport is an integral part of today's society. It is important, as it fills the basic need of going from one location to another. This need is shared by passenger and freight transport. As economies continue to grow, the demand for transportation tends to increase correspondingly. Private car ownership gives a freedom of movement which is highly valued. As the world economy grows, trade increases, and more and more goods are being moved. Reduced mobility impedes development, while greater mobility is a catalyst for development. Therefore, mobility is a reliable indicator of development (Rodrigue *et al*., 2006). Apart from being of critical importance in today's society, transport is also responsible for a number of (negative) external effects, such as congestion, air pollution and carbon dioxide emission (an important greenhouse gas).

In recent years, the need for mitigation of climate change has been more and more acknowledged by policymakers, perhaps also instigated by the release of Al Gore's 'An inconvenient truth' and the 2007 IPCC assessment reports. Europe has set ambitious targets for the short term and the long term, to reduce the anthropogenic emissions of greenhouse gasses. Several European Member States have set their own climate targets, which are even more ambitious than those set for Europe as a whole. The Netherlands is one of these countries.

For the year 2020, the Netherlands has set the target of reducing greenhouse gas emissions by 30%, compared to 1990 levels. In addition, the Dutch Government also has committed itself to an energy saving tempo of 2%, per year, and a share of 20% renewable energy, by 2020. The Netherlands has also set specific targets per sector, including one for the transport sector.

In a first assessment on the attainability of the Dutch climate targets, the potential for emission reduction in the period between 2010 and 2020 was evaluated by ECN and MNP (ECN/MNP, 2007). This study showed that if climate policy in the European Union is very successful, an emission reduction of 13 to 17 Mt CO_2 equivalents, by 2020, would be attainable in the transport sector. With a less successful European policy, but a still heightened effort compared to current policy, the emission reduction potential would decrease to between 9 and 14 Mt CO_2 equivalents. Apart from the substantial bandwidth (9 to 17 Mt), the study stressed that it should not be interpreted as a final assessment, and that more research needed to be done, to assess the real contribution to emission reduction from the transport sector. Important uncertainties, such as scenario assumptions, oil price developments, definition of costs, and the reduction potential of biofuels, were only partly addressed in the assessment. The policy programme *Clean and Efficient* has set an emission reduction target for the transport sector of 13 to 17 Mt CO_2 by 2020 (VROM, 2007).

Very recently an update of the assessment was carried out by ECN and PBL, based on a new emission projection and recent information on the progress of European and Dutch policy. This update concluded that the emission reduction potential of the policy programme *Schoon en Zuinig* is between 9 and 15 Mton in 2020 (ECN/PBL, 2009), comparable to the original evaluation.

This report is structured around three issues that give more insight into the relation between the medium-term and long-term climate targets for the Dutch transport sector. These issues are positioned around the three following questions:

1. *What greenhouse gas (CO_2) emission reductions are feasible in the long run (2050) in the transport sector? What type of measures are required to meet long-term targets?*
2. *Which measures for 2020 are considered by the Dutch government for the transport sector and how effective and efficient are they?*
3. *How do 2020 measures relate to 2050 targets? Do the medium-term oriented measures aid (sufficiently) in meeting 2050 targets?*

Question 1

Current medium-term targets (2020) are a stepping stone towards long-term targets. Cross-sector CO_2 emission reductions of 65 to 95%, compared to 2000 levels, are expected to be needed in the long term to mitigate global warming. Since transport volume is expected, approximately, to double in this period, an additional effort is required of this sector. This report will look at the available options for the transport sector to meet long-term climate targets. Different possible futures are considered by looking at scenarios, and the main barriers to realise these scenarios are identified.

Question 2

This report will also look at transport measures that are currently being implemented or considered by the Dutch Government, to meet medium-term targets (2020). The Dutch policy programme *Schoon en Zuinig* contains a number of transport measures that will be subjected to a qualitative assessment. The qualitative assessment will score the measures on a number of criteria, including effectiveness, flexibility (lock-in risk), cost effectiveness, and incentive for technological innovation.

The issue of Dutch dependence on international (European) cooperation and agreement on climate policy is included in the analysis. Co-benefits and trade-offs for other sustainability issues (air quality, energy security, etc.) following from climate measures in the transport sector, will also be addressed.

Question 3

The central question in this report is whether the measures currently considered and prepared by the Dutch Government to meet the 2020 climate targets either (1) help (substantially) to meet long-term emission reduction targets, or (2), to a certain extent, may distort meeting long-term targets. The reason for addressing this issue is that there are possible trade-offs between medium-term and long-term climate targets. Significant investments in technologies that can reduce emissions by 2020, but which are nevertheless insufficient for meeting long-term reduction requirements, might cause technology lock-in. Once these technologies have a substantial market share, the chances diminish for other, innovative and more effective measures (currently not available) to enter the market. Lock-in entails needing a bigger effort to meet 2050 targets.

In answering these main questions, much attention was given to uncertainties associated with long-term predictions and analyses. Apart from identifying main barriers, the co-benefits of climate policy were also mapped, where possible. Cost estimates of (long-term) transport climate policy have not been quantified in this report. However, the cost-assessment issue was addressed, qualitatively, from the perspective of social welfare economics. CO_2 abatement measures in transport may result in behavioural changes associated with welfare costs, which are difficult to quantify.

Answering, or at least addressing these questions will improve the understanding of the impact of Dutch climate targets for transport, and of the challenges for policymakers.

2

Transport and climate change: trends and uncertainties

A good way of expressing to which extent a certain sector affects the climate system, is through the so-called radiative forcing potential. Radiative forcing or warming potential is determined by the different emission compounds that are emitted from the transport sector. Transport produces a variety of emissions, ranging from direct greenhouse gas emissions (mainly CO_2) to O_3, NO_x, VOC and CO, which indirectly influence warming, and particulates (PM). Some of these components have a warming effect, whereas others have a cooling effect. As the lifetime of components differs, so does their impact on warming and cooling. When all these effects are taken into account, the contribution from transport to global warming is approximately 15% (Fuglestvedt *et al*., 2008). Moreover, considering that the share in total worldwide greenhouse gas emissions from transport is expected to rise to between 30 and 50%, by 2050 (whereas today it is around 20-25%), the radiative forcing is expected to increase.

The transport sector is an important contributor to greenhouse gasses emissions. Globally, contributions currently amount to nearly 20%, but are expected to increase to almost 30%, mainly due to the economic growth in China and India (IPCC, 2008). In Europe (EU27), transport has a share of around 22% in the total of greenhouse gas emissions (EEA, 2008). Between 1990 and 2005, the share of road transport in all transport-related CO_2 emissions increased by 32% (DG TREN, 2008), to a total of 72%.

2.1 Trends in CO_2 emissions in the Netherlands

The amount in greenhouse gas emissions from transport in the EU27 was approximately 990 Mt, in 2005 (EEA, 2008). The reported CO_2 emissions from transport in the Netherlands, in the same year, were 40 Mt (PBL, 2008a), which in a global perspective is not substantial, but on a national level corresponds to 20% of total greenhouse gas emissions.

The reported Dutch transport emissions of 40 Mt have an uncertainty margin of about 4%, implying that the Dutch emissions are likely[1] to be between 38 and 42 Mt CO_2 (PBL, 2008a).

Transport emissions in the Netherlands have grown by over 30%, since 1990. This does not mean that attempts to reduce CO_2 emissions have been unsuccessful. Without the measures that have been implemented since 1990, CO_2 emissions would likely have been higher. According to Van Dril and Elzenga (2005), if it was not for the measures formulated in the Netherlands' Climate Policy Implementation Plan (VROM, 1999), by 2010, the emissions from transport would be 1.0 to 1.4 Mt CO_2 higher.

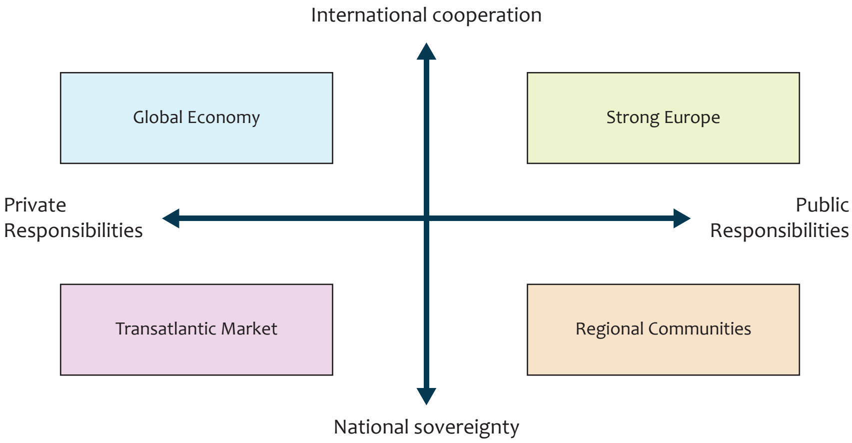
2.2 Future emissions from transport

To be able to say anything about the potential emission reductions within the transport sector, it is necessary to estimate future emissions. A common approach for policy evaluation purposes is to construct emission scenarios based on current legislation. Such scenarios are often referred to as *projections* which provide the basis against which the effects of additional measures are offset.

In 2006, the study *Welfare, Prosperity and Quality of the Living Environment* (WLO) was completed (CPB/MNP/RPB, 2006). The study assessed the long-term effects of the current policy, given the international economic and demographic context of the Netherlands. By exploring how land use and various aspects of the living environment might develop in the long run (2040), the study showed when policy objectives might come under pressure, and which new issues might emerge. Four scenarios were constructed, varying around two key uncertainties: (1) the extent to which countries are prepared to cooperate, and (2) the reform of the public sector. This is illustrated in Figure 2.1.

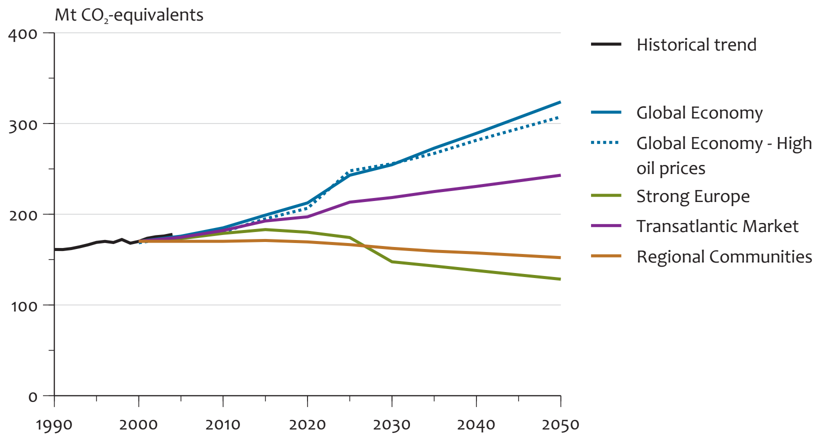
1 'Likely' is an IPCC term which means that the probability that greenhouse gas emissions of transport are between 38 and 42 Mton greater than 66%.

Key uncertainties of scenarios **Figure 2.1**



Orientation of the four WLO scenarios in relation to international cooperation and public-sector involvement.

CO_2 emission **Figure 2.2**



Trend in total CO_2 emissions in the Netherlands for the period from 1990 to 2050, for the four WLO scenarios.

Differences in assumptions on economic growth, demographic growth and the reform of the public sector also impact greenhouse gas emissions, as is shown in Figure 2.2[2]. Most apparent is the substantial difference between the projected emissions in Global Economy (GE) and Strong Europe (SE). Emissions roughly vary between 125 and 325 Mt.

The key uncertainties around which the WLO scenarios were constructed also impact developments within the transport sector. Larger demographic growth, for example, will lead to a larger growth in mobility. And larger economic growth will lead to higher incomes and to people buying larger cars that emit more CO_2. Also, economic growth will increase trade in transported goods which also increases emissions. Figure 2.3 shows how the differences in the four WLO scenarios resulted in different CO_2 emission projections for the transport sector.

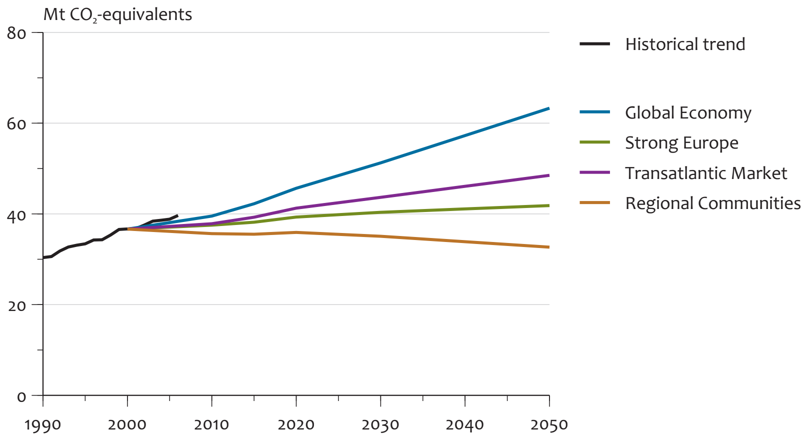
2 The year furthest into the future, in the WLO scenarios, is 2040. For the purpose of this study, the emissions in 2050 have been calculated based on a linear extrapolation between 2030 and 2040

It is clear that the emission dispersal in the WLO scenarios is also significant for the transport sector.

Before looking in some more detail at the emission trends for the transport sector according to the WLO scenarios, it is important to note that the SE and RC scenarios are not strictly based on the then current legislation. In SE, fairly ambitious climate policy for the energy and transport sectors was assumed, after 2020, which makes this scenario rather unsuitable for business-as-usual analyses. In both SE and RC, additional emission legislation, limiting NO_x and particulate matter emissions from road vehicles, was assumed. These measures, however, do not significantly influence emissions of greenhouse gasses from the transport sector.

For the transport sector, the additional policy in the SE scenario is a gradual lowering of CO_2 emissions from passenger cars, per kilometre, to a level of 120 g/km (the level is currently around 160 g/km). The EC has recently implemented legislation requiring new passenger cars to have a CO_2 emission limit of up to 130 g/km as of 2015, with an agreement to

CO_2 emission from transport **Figure 2.3**



Trend in CO_2 transport emissions (excluding sea shipping and aviation) for the period of 1990 to 2050, for four WLO scenarios.

assure 10 g/km lower emissions via additional measures (e.g. energy efficient tyres). Figure 2.3 shows that this measure is insufficient to create a downward trend as result of the fairly high mobility growth (40% between 2000 and 2020).

Figure 2.3 excludes the emissions from aviation and sea shipping. Officially, the emissions from these sources are not attributed to individual countries. Therefore, the Netherlands is not formally accountable for these emissions. It should be noted, however, that the share in global greenhouse gas emissions from these sectors are far from negligible (see textbox *Aviation and Sea Shipping*).

Figure 2.3 clearly shows the substantial range for expected emissions in 2020 and 2050. According to the WLO study, CO_2 emissions from transport in 2050 might vary roughly between 30 and 65 Mt. This is an indication of the substantial uncertainty (by over a factor of 2) that is the result of differences in underlying assumptions.

2.3 Oil price

The oil price has a large impact on CO_2 emissions from the transport sector, and also influences the impact of CO_2 reduction policies. As oil prices increase, the price of refinery products for passenger cars and trucks (petrol, diesel, LPG) also increases. Consequently, consumers and companies have to spent more on transport and will try to reduce additional fuel expenses.

In the short term, a high oil price will result in reduced car use and in an increase in fuel-efficient driving. Consumer driving (e.g. social visits and shopping) will react much stronger than business-related driving.

Moreover a high oil price will stimulate consumers to buy more energy-efficient vehicles. This effect takes place at a medium time scale, related to the replacement rates of passenger cars. In addition, a high oil price will increase the availability of fuel-efficient vehicles, since technical measures for improving fuel efficiency will become more cost effective.

Textbox: Aviation and Sea shipping

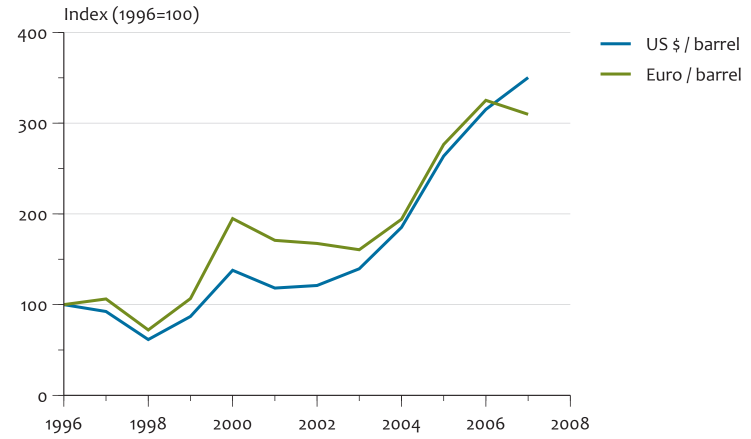
Currently, hardly any greenhouse gas emissions from shipping and aviation are attributed to individual countries. As a result, there have been few policy measures implemented which aim to reduce emissions from these sectors. Both sectors, nonetheless, have a substantial share in global greenhouse gas emissions. It is estimated that aviation is responsible for approximately 4% of global CO_2 emissions and that this share is expected to increase to 5%, by 2020. The climate impact is estimated to be 2 to 4 times greater than from the CO_2 emissions alone because at great altitude emissions result in increased radiative forcing (IPCC, 1999).

Shipping emissions are estimated to contribute 4% to global greenhouse gas emissions (IMO, 2007). The climate impact of sea shipping may increase if regulations for the treatment of exhaust emissions from ships is tightened or the sulphur content of fuel is lowered. Recently, the International Maritime Organization (IMO) has agreed on a step-wise lowering of the sulphur content of fuel for global shipping (IMO, 2008). This will result in a decrease of particle emissions, which have a cooling effect (Annema, 2007).

The European Commission currently considers including aviation and possibly also sea shipping in the European Emission Trading Scheme (EU-ETS).

Oil prices

Figure 2.4



Influence of exchange rates on oil prices (yearly mean levels, real prices).

Relation between oil price and transport fuel price

Table 2.1

Oil price			Petrol price			Diesel price		
$/barrel	€/barrel	€/GJ	€/GJ (excl. tax)	€/GJ	€/litre	€/GJ (excl. tax)	€/GJ	€/litre
40	29.2	5.0	10.0	37.2	1.22	8.9	23.3	0.84
65	47.5	8.1	13.6	41.4	1.36	12.5	27.6	0.99
120	87.6	15.0	22.1	51.6	1.69	21.0	37.7	1.35

Relation between oil price and transport fuel price (at fuel stations) in the Netherlands (2007 prices)

Furthermore, a high oil price will stimulate transport companies to improve the load factor of transport, for instance, by improving logistics, and by bringing about structural effects, such as a shift from delivery on demand towards a less frequent delivery of goods, driven by stock levels.

The trend in oil prices is a fundamental input for scenarios. The historical trend, from 1997 to 2003, was used for establishing oil prices per WLO scenario. As Figure 2.4 shows, oil prices have increased substantially, since 2003. In two scenarios, the oil price was fixed on the 2003 level, up to 2040. In the other two scenarios, the oil price was increased, slightly, to between 28 and 30 $\$_{2000}$ per barrel. As oil prices have increased substantially, a 'high price' variant was also developed with a peak in the period between 2005 and 2007 of 48 $\$_{2000}$ per barrel, decreasing to 38 $\$_{2000}$ per barrel in 2010, and ending at 45 $\$_{2000}$ per barrel in 2040.

After the oil price peaked to over 150 $/barrel, it dropped to 120 $/barrel by late July of 2008, and, by the end of 2008, the price had dropped to levels below 50 $/barrel. This makes clear that oil prices are very volatile and its future development is unclear. Since the costs of new oil projects are in the range of 60 to 70 $/barrel (Fugro, 2008), oil prices are not expected to go much below 40 $/barrel, structurally.

An oil price of 22.5 $\$_{2000}$ per barrel is in real Euro terms equivalent with a 38 $\$_{2007}$ per barrel and the high oil price variant with 48 $\$_{2000}$ per barrel in 2007 and comparable level in 2040, is equivalent with 82 $\$_{2007}$. One could argue that a large part of the actual increase in market price, in dollars, is an effect of the weakening dollar.

Table 2.1 shows the mean relation between the crude oil price and the fuel price at fuel stations, based on an analysis of historical data from 2002 to 2005. The tax levels of January 2008 are used in this table (different fuel tax for petrol and diesel and a VAT of 19%; each year, fuel tax levels are corrected for inflation). The $ 40 level was applied in the GE scenario of the WLO, the $ 65 level in the GE High Prices (GE HP) variant and the $ 120 level applies to the situation of mid 2008. At the higher oil prices of 65 and 120 $/barrel, the petrol prices rise with 12% and 39%, and for diesel prices this is 18% and 62%, compared to the petrol price level at oil prices of 40 $/barrel.

According to Geilenkirchen *et al.* (2009 in preparation), a fuel price increase of 1% will lead to a decline in passenger car fuel consumption on the long term of 0.6% to 0.8%. Assuming that fuel prices remain at least at GE HP fuel price levels, the consumption by passenger cars will be at least 7 to 11% lower than was calculated for the GE scenario. However, if fuel prices stay at the high level of mid 2008, consumption on the long term can be expected to be around 20% lower than in the GE scenario. Considering that the emissions from passenger cars in GE will be approximately 26 Mt CO_2 in 2020, the effect of higher oil prices on emissions could be 2 to 8 Mt.

2.4 Policy targets

Climate policy targets have been set both by the European Commission and by the Dutch Government. The European targets are for the medium term (2020) and the long term (2050 and beyond). The Dutch climate targets focus on 2020. This paragraph will give an overview of European and Dutch climate targets, and, for the latter, also of the specific sector targets laid out in the Dutch Clean and Efficient policy programme. For convenience, since this report focuses on the medium to long term, it ignores the Kyoto protocol, which sets emission reduction targets for the period from 2008 to 2012.

2.4.1 Europe

Policy targets for 2020

In January 2008, the European Commission announced its Energy and Climate policy package. An important aspect of these proposals is the introduction of an EU wide cap for companies in the European Union Emission Trading Scheme (EU ETS). If the proposal is passed, individual Member States would no longer have a specific target for the sectors involved in ETS (Olivier *et al.,* 2008). Since all European companies would trade in the reformed ETS, national governments would no longer control the emission output of their country's companies. Moreover, it would become irrelevant in which country emission reduction takes place. The ETS system with an EU wide cap would ensure (if properly monitored) a drop in EU emissions of 21% by 2020, compared to 2005. Moreover, the system would ensure that mitigation measures are implemented where they are cheapest. Countries with relatively energy-efficient ETS companies, such as in the Netherlands, would invest less in mitigation measures, since it would be more economical for them to buy CO_2 rights. The actual emission reduction would then occur in countries with less energy-efficient companies that could implement still relatively cheap mitigation measures.

In essence, Member States, including the Netherlands, would lose control over the emissions from the industry and energy sector. For the Netherlands, this would amount to approximately 50% of national greenhouse gas emissions (Olivier *et al.,* 2008).

In the Energy and Climate package, the European Commission also sets targets for sectors outside of the ETS. The most important of these so-called non-ETS sectors are transport, households and the built environment. The targets for these sectors differ per Member State. The Netherlands would need to reduce emissions from non-ETS with 16% by 2020, compared to 2005. Assuming an equal distribution of emission reduction over non-ETS sectors means that the European Commission would require the Netherlands to reduce 13 Mt in emissions from the transport sector, by 2020.

Policy targets for 2050 and beyond

In the long term, the European Commission wants to limit the atmospheric concentration of CO_2 to 450 parts per million (ppm). It is expected that such concentrations would limit the global temperature increase to a maximum of 2 degrees Celsius. Stern (2006) concluded that, for industrial countries, this would entail an emission reduction of 60 to 80%, compared to 1990 levels. The Bali Action Plan, signed in December 2007, also acknowledges the need for drastic emission reductions, based on the Fourth Assessment Report of the IPCC (2007). This report speaks of emission reduction requirements for industrialised countries of 85 to 95% by 2050, compared to the year 2000, to ensure atmospheric CO_2 concentrations of no more than 450 ppm.

Combining the targets named in Stern (2006) and IPCC (2007), translates into a long-term emission reduction target of approximately 65 to 95%, compared to the year 2000. This is the bandwidth for the long-term (2050) emission reduction requirement that is used throughout this report.

2.4.2 The Netherlands

The Netherlands also has formulated climate policy targets for the year 2020. These targets were first put down in the coalition agreement, in early 2007. The targets are threefold:

1. 30% greenhouse gas emission reduction, compared to 1990 levels;
2. energy saving of 2% per year, up to 2020;
3. 20% share of renewable energy.

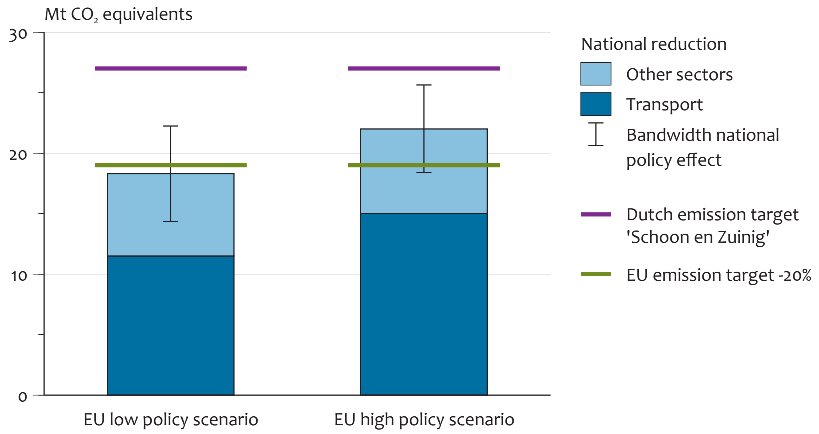
These targets are more ambitious than the European targets. In 2007, ECN and MNP (now PBL) calculated in a preliminary assessment that this would entail an emission reduction of 97 Mt (all sectors) in the Global Economy Scenario with a high oil price correction (see Section 2.3). The feasible contribution of the transport sector was 9 to 14 Mt, in the case of less successful EU policy, and 13 to 17 Mt, with successful EU policy. The main difference between these so-called 'EU low' and 'EU high' policy scenarios is the assumption on CO_2 emission legislation for passenger cars. In 'EU low' it is assumed that, by 2015, new cars and vans will have an emission factor of 130 g CO_2/km and that this will remain constant from then on. In 'EU high', new passenger cars have an emission factor of 95 g CO_2/km, by 2020.

Figure 2.5 shows the contribution from the transport sector in these two EU scenarios. In 'EU low', 60 to 65% (9 to 14 Mt) of the required reduction for 'non-ETS' sectors comes from transport. If EU policy is more successful, transport contributes 65 to 70% (13 to 17 Mt) to the required reduction for 'non-ETS' sectors.

The Dutch Government set the transport target at 13 to 17 Mt by 2020. Both the Dutch and European targets for the transport sector are given in Figure 2.6. It follows that the EU target, set at -16% compared to 2005, is comparable with the lower limit of the bandwidth of the Dutch reduction target of 13 to 17 Mt.

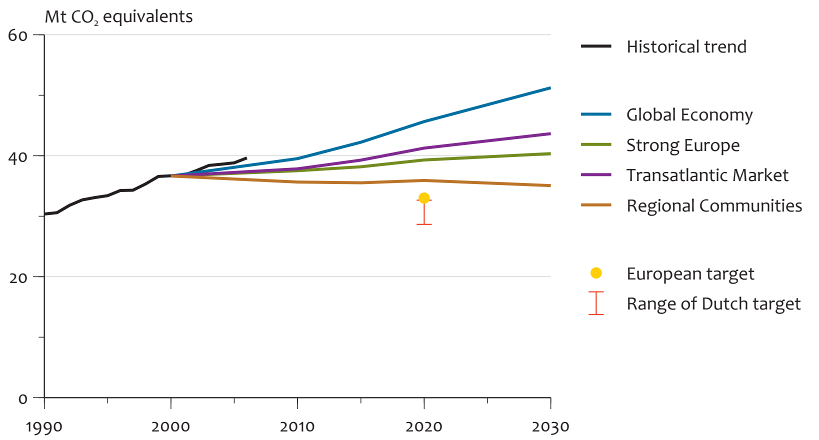
It is clear from Figure 2.6 that in the GE scenario with high oil prices, which was used for the evaluation, a substantial effort would be required, to bring the targets within reach. The trend in GE points upwards, but should turn around to an absolute downward trend, in a matter of years. For illustrational purposes only, Figure 2.6 also contains the CO_2 emissions in TM and RC. It is clear that, in these two scenarios, the effort needed for reaching the targets would be smaller. It is, however, not entirely fair to compare the target

CO_2 emission reduction non-ETS sectors 2020 — Figure 2.5



Share of transport in emission reduction required to meet Dutch and European climate targets. 'Other' represents the built environment, agriculture and households.

CO_2 emission from transport and targets — Figure 2.6



EU and Dutch emission reduction targets for the transport sector (excluding sea shipping and aviation) compared to 'current legislation trends' in CO_2 emissions in GE and TM.

of 13 to 17 Mt with the projected emissions in TM and RC, since it is based on the effects of available measures in the GE scenario. This scenario has relatively high growth, accompanied by high emissions, therefore, the potential for emission reduction through specific measures is also relatively high. In other words, if the TM or RC scenarios had been used in the evaluation, than the reduction potential would not have been as high as 13-17 Mt. The same applies to the SE scenario, which incorporates some climate related policies that reduces the reduction potential of specific additional climate measures.

2.5 Concluding remarks

What hopefully has become apparent from this chapter is that forecasts on future emissions are inherently uncertain. Scenario assumptions, such as demographic and economic growth, oil-price developments, spatial planning, and the willingness to cooperate on international level, determine the demand for mobility and the potential for success of public policy. In assessing the potential for CO_2 reduction in the transport sector, it is essential to recognise these uncertainties and integrate them in the analyses. Moreover, it is not uncommon in ex- ante evaluations that, from a series of scenarios, ultimately only one scenario is selected. The ex-ante evaluation of the policy programme *Schoon en Zuinig* of the Dutch Government is an example of a single-scenario evaluation, based on the Global Economy scenario (ECN/ MNP, 2007). The reasoning behind choosing the scenario with the highest demographic and economic growth, and, consequently, also the highest environmental pressure, is that illustrates the worst-case scenario. If enough of the measures from this scenario are taken 'in reality', this provides the highest chance for the targets to be met.

However, it should be noted that in a scenario with high demographic and economic growth the emission reduction potential of measures is also large. GE, for example, is a scenario with high economic growth and technological advancement. Expensive, but effective technological measures might be more successfully implemented in this scenario than in that of Regional Communities. A fair assessment of the reduction potential of measures, therefore, should include calculating the effects for all available scenarios. This would provide a more accurate estimate of uncertainties.

In the very recent update of the assessment ECN and PBL a different approach was adopted including a more integrated approach of the scenario uncertainties ranging from GE to RC (ECN/PBL, 2009).

Also note that the uncertainty about future developments is the reason behind having more than one scenario. The WLO scenarios provide four different, but just as likely future worlds, in which the different dilemmas can be assessed that society and policymakers could be confronted with. Choosing only one of these scenarios, could exclude relevant dilemmas from the analysis.

The Dutch Government aims to achieve the 'non-ETS' climate target mainly through transport measures. For this target, a set of measures was adopted, based on the assumption that EU climate policy for this sector would be successful. However, if the EU climate policy would be unsuccessful, then meeting the Dutch climate targets would be at risk and additional measures would be needed at the national or EU level. This situation could occur when negotiations on CO_2 limits for road vehicles were to be delayed or sustainability criteria for biofuels could not be agreed upon in time (see also Chapters 3 and 4).

The next two chapters will examine the ways and the measures by which long-term (2050) and medium-term (2020) emission reduction targets might be achieved.

The long term (2050)

3

3.1 Contribution from transport to long-term climate targets

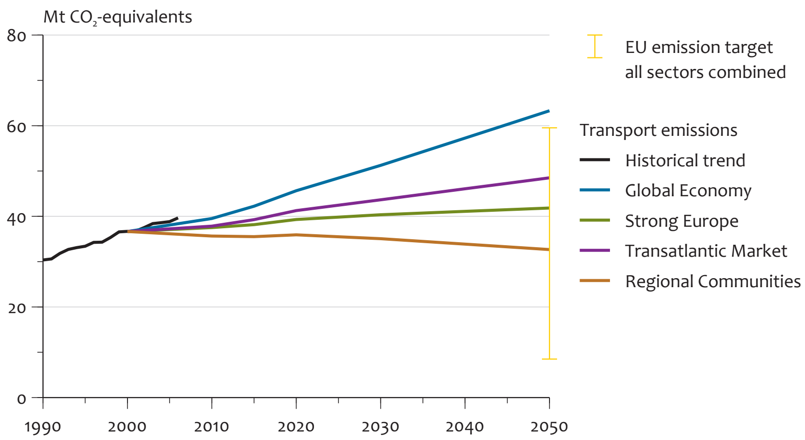
Combining the estimates of Stern (2006) and IPCC (2007) results in a long-term emission reduction requirement for industrialised countries of 65 to 95%, compared to 2000 (see Section 2.4.1). One of the logical questions on how to reach these targets, would be that of how large the contribution from the transport sector should be.

The total amount of emissions allowed from all sectors combined, in 2050, with a required overall reduction of 65%, amounts to approximately 60 Mt CO_2 eq. An emission reduction of 95% would allow for a total in emissions from all sectors combined of approximately 10 Mt CO_2 eq. This can be compared with the emissions projected for the transport sector, for 2050, which are 35 to 65 Mt, representing the range between the scenarios Regional Communities and Global Economy. Therefore, at emission reductions of 95%, it is inevitable that the transport sector would have to contribute to the mitigation of CO_2 eq emissions (even more so when aviation and sea shipping would be added to these numbers). At emission reductions of 65%, however, it is theoretically possible to apply all mitigation measures to non-transport sectors (see also Figure 3.1).

These numbers and Figure 3.1 both indicate that the way mitigation measures are distributed over the sectors could have dramatic implications for the long-term policy strategy for the transport sector. With close to zero emissions from other sectors, in 2050, the transport sector could suffice with a stabilisation of emission at 2000 levels. Since transport emissions may double up to 2050, due to mobility growth, even stabilisation would still require a substantial effort. As will be shown in Section 3.2, the stabilisation of emission reductions would be feasible with optimisation of conventional vehicle technology. If less ambitious targets would be set for the other sectors and transport would have to contribute equally to the overall targets, conventional vehicle technologies would no longer be feasible and a transition towards new advanced technologies, such as electric vehicles or fuel cell vehicles, would be a necessity for maintaining current mobility needs.

One of the criteria for burden sharing between sectors for achieving emission targets is the cost-effectiveness of measures. Achieving targets at the lowest costs (to society) may be viewed as a sound principle. Chapter 5 will show, however, that different cost calculation methods can result in very different outcomes, and most likely also in a different distribution of sector targets. If governments want to reach climate targets at the lowest cost possible they would need to know

EU emission target for national CO_2 emission **Figure 3.1**



Emission projection for including transport (excluding aviation and sea shipping) in the Netherlands and emission reduction targets for all sectors combined in 2050.

the marginal cost curve, including welfare costs, of all available measures in all sectors.

Finding the marginal cost curve of CO_2 mitigation measures for all sectors is widely beyond the scope of this report. From this point on, we have assumed that the transport sector and other sectors have to contribute 65 to 95%, compared to 2000 levels.

The options for achieving long-term emission reductions of 65 to 95% in the transport sector are described in the following sections. A rough back-casting approach was chosen, meaning that barriers have been identified in the different pathways to long-term emission reductions.

The options, or pathways, considered can be split into four categories (King, 2007):

- Fuel CO_2 efficiency, referring to the amount of CO_2 associated with each unit of energy stored in the fuel. All CO_2 emitted during the life cycle of the fuel should be included, namely (1) extraction or farming of the primary energy sources, (2) transport to fuel production and processing plants, (3) conversion of energy sources into road fuel, (4) fuel distribution to filling stations, (5) fuel use in vehicles (exhaust emissions).
- Vehicle efficiency, referring to how efficiently a vehicle engine converts the fuel into energy for propulsion. Engine efficiency, aerodynamics and weight are important factors determining vehicle efficiency.
- Driving efficiency, referring to how efficiently a driver uses the car over a given distance. Avoiding rush hours, limiting transported weight, reducing the maximum speed and smoother driving will all increase driving efficiency.
- Distance travelled, since every kilometre travelled requires energy, reducing the amount of kilometres will limit energy consumption and, therefore, CO_2 emissions.

3.2 Passenger cars and light-duty vehicles

3.2.1 Fuel efficiency and vehicle efficiency

When reviewing long-term climate targets and emission reduction of up to 95%, the discussion on fuels becomes very prominent. New fuel types play a crucial role in bringing long-term targets within reach. These should be very low-carbon or zero-carbon fuels, meaning that well-to-tank CO_2 emissions are very limited. Thus, a substantial part of the climate mitigation challenge is shifted towards the energy production and refinery sectors.

Electricity cannot be used in conventional Internal Combustion Engine Vehicles (ICEVs). High bioethanol blends require modifications to conventional cars. Battery electric vehicles (BEVs) or fuel-cell electric vehicles (FCEVs) will have to enter the market in substantial amounts, to ensure that emission reductions of 65 to 95% are realised.

Since fuel CO_2 efficiency and vehicle efficiency are closely intertwined, in this report they are both considered together. A few scenarios (combinations of vehicle types and fuel types) for the long term will be discussed. These are:

- BEVs in combination with electricity from (1) fossil fuel with carbon capture and storage (CCS) and (2) biomass, solar, wind, hydro, nuclear and others;
- FCEVs in combination with hydrogen from (1) fossil fuel with CCS and (2) biomass, solar, wind, hydro, nuclear and others;
- ICEVs hybrids in combination with advanced biofuels;

It should be made clear that these scenarios do not cover the complete range of options available for 2050 and beyond. They are used here to illustrate which important barriers may be encountered, and what the range in reduction potential roughly is.

BEVs in combination with low-carbon electricity

Battery electric vehicles

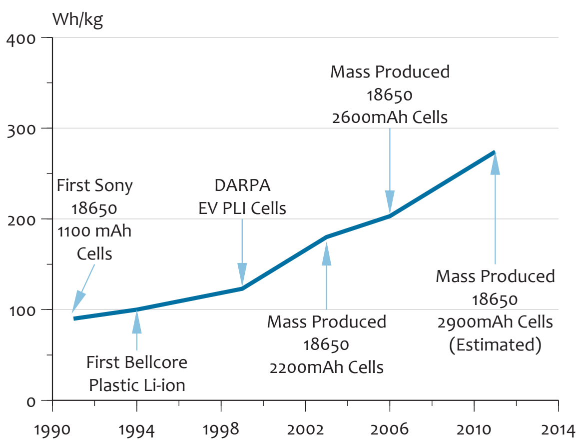
Cars with electric engines on board can be divided into hybrids, plug-in hybrids, and all-electric vehicles. Only the last two categories store energy from the national electricity grid in on-board batteries. Depending on the size of the batteries and the use of the car, plug-in hybrids are able to drive 40 to 50% of the time powered by electricity (Passier *et al.*, 2008). When their battery is depleted, they can switch to power generated by their on-board internal combustion engine, thereby offering a much larger driving range than all-electric vehicles. However, plug-in hybrids are inevitably more expensive, due to the additional internal combustion engine.

Batteries are the crucial technology for electric vehicles. Batteries for electric vehicles need to (1) have an acceptable price and lifetime, (2) be sufficiently small per kWh (high energy density) and physically manageable, and (3) be safe (Passier *et al.*, 2008).

Currently, battery prices range from 10,000 - 15,000 euros, with a battery capacity of 20 to 30 kWh. Depending on the vehicle size and weight, the driving radius is limited to about 150 to 300 kilometres (BERR, 2008; Nagelhout *et al.*, 2009). However, there is a realistic perspective that battery prices will go down at sometime in the not too distant future and that the energy density will increase especially when mass production starts (BERR, 2008). Battery research for other purposes (laptops, mobile phones) has contributed to the improvement of batteries, and this development is expected to continue in the future (see Figure 3.2). Batteries with a capacity suitable for electric cars (Li-Ion) are currently mass-produced by two suppliers, AESC (joint venture of NEC and Nissan) in Japan, and A123, an American company producing in East Asia. These type of batteries charge slowly (e.g. overnight). Batteries that can be charged faster, in combination with a long lifespan, are not expected to become available within the next three years (BERR, 2008).

Batteries in hybrids are usually operated within a narrow segment of the charge-discharge curve, to optimise energy efficiency and battery life. In contrast, plug-in hybrids and all-electric vehicles require batteries that can be discharged as deep as possible, to increase the driving radius. For comparable driving distances with ICEVs, the amount of power per kg should be around 400 Wh/kg.

Energy density of batteries **Figure 3.2**



Energy density of batteries, from the past to the near future (Hansen, 2008).

Furthermore, analysis in (Kroon, 2008) indicates that the desired increased production levels of batteries should not present fundamental problems, given the global availability of lithium, and the current and expected annual production.

A large-scale introduction of electric vehicles requires an expanded electricity infrastructure with public and private charging facilities. If the business case for vehicles that use electricity is profitable, this market perspective is expected to be sufficiently attractive to stimulate the required expansion of the infrastructure (Hanschke *et al*., 2009). The classical chicken-and-egg problem (availability of electric vehicles and sufficient charging locations) is not expected to create a major barrier for the successful introduction of electric vehicles. It should be noted, though, that other chicken-and-egg problems remain, such as the costs of batteries – which could only go down if mass production starts – will put a break on initial sales, which in turn hinders the step up towards mass production. There also might be spatial development barriers (most likely to occur in cities) that prevent the installation of charging points at particular locations. Another barrier, and there may be more, is people's possible unwillingness to make the transition to electric vehicles, if (in the early stages) it would entail having to park at specific locations were charging points are available.

Electricity

The large CO_2 reduction potential of electric (or plug-in electric) vehicles is related to the fact that stationary electricity production can be largely decarbonised. This decarbonisation would require electricity generated either from renewable sources or from fossil fuels with a strong penetration of carbon capture and storage (CCS). CCS, in this case, is essential to prevent the emission reduction in transport to be offset by increased emissions from power generation, either within the Netherlands or abroad.

The full potential of CCS has not yet been unequivocally quantified. According to a recent study by Clingendael (Van den Heuvel, 2008), the CO_2 storage in the Netherlands will have to rely on the availability of depleted gas fields. In a realistic case, the Dutch subsurface could technically store approximately 35 to 40 Mt/a of CO_2, for a period of 40 years (equal to the typical lifespan of a power station).

An alternative route would be electricity production from renewable sources, including wind, hydro, geothermal and photo-voltaic. Nuclear electricity production can also provide a (near) zero-emission alternative. In the Netherlands, there is potential for wind, hydro and photo-voltaic energy production, but spatial planning issues create barriers for a fast growth in production. Wind at sea is a viable option, although spatial planning is an issue, since the North Sea holds valuable nature areas, and wind parks at sea might also interfere with commercial fishing and sea shipping.

Another barrier for the large-scale introduction of electric vehicles is the electricity infrastructure required. In the Netherlands, many people live in flats. Therefore, only about 1.5 million households would have the option of installing home charging facilities to charge their car on their own property. Consequently, many 'charging points' will need to be constructed at public locations, including employment locations. Some electric-vehicle concepts rely on the installation of battery exchange stations as a solution to the limited driving radius for electric vehicles. Large-scale implementation of the electric-vehicle infrastructure will take time. Charging points (such as water and power distribution networks and telecommunication networks) could be designated as regulated assets, typically enabling the service provider to cover installation and operating costs and achieve an adequate return on investment. This could be an incentive for utility firms to install them (BERR, 2008).

Electricity in the transport sector may also result in a benefit for electric power companies. Electric vehicles could alleviate the mismatch in energy production and consumption (e.g. cars could be instructed from a control centre to start charging when the wind is blowing). This so-called vehicle-to-grid (V2G) technology, therefore, is potentially very attractive to electricity companies. Off-peak energy consumption can occur through overnight charging of electric vehicles. Most cars can be fully charged from a home charging point within a maximum of 8 hours for a fully depleted battery; average recharging times are expected to be between 2 and 6 hours.

For the reduction of CO_2 emissions through overnight V2G electricity storage in electric vehicles, it is essential that the electricity stored is low carbon. Currently, in the Netherlands, electricity which is generated at night mostly comes from coal power plants (apart from a small contribution from wind) without CCS and with high emission levels. This is because gas power plants, which can be operated more flexible, are switched off during the night when electricity demand is low. Coal power plants cannot be fully switched off and, therefore, operate at low power during the night. Consequently, without special regulations, additional electricity demand from charging vehicle batteries at night would increase coal power based production, associated with high levels of CO_2 emissions.

If the above mentioned barriers could be overcome, and if zero-carbon electricity for the transport sector could be produced in sufficient quantities, BEVs would have substantial potential for reducing CO_2 emissions from passenger car transport. The combined efficiency of the energy chain of electricity transport from the production plant to the car, battery charge, discharge, on board power electronics and electric engine, would add up to about 85%.

FCEVs in combination with low-carbon hydrogen

Fuel-Cell Electric Vehicles

A fuel-cell electric vehicle uses fuel cells to convert hydrogen (or other energy carriers) into electricity, which in turn is used to propel the vehicle. Currently, fuel-cell vehicles are available only in prototype and demonstration models. The main barriers to commercial utilisation in the long run are:

- storage of hydrogen within the vehicle: safe effective on-board storage is one of the biggest hurdles for hydrogen-powered vehicles when aiming for a driving radius of about 500 kilometres. Compressed hydrogen in tanks would take up much space inside the vehicle and provide additional weight, which reduces vehicle efficiency. Liquid storage is only possible at very low temperatures (-253 degrees Celcius) and requires a substantial amount of energy.
- operating temperature: fuel cells do not operate at temperatures below freezing without additional measures. This would limit the utilisation of fuel-cell vehicles in cooler regions.
- costs: the cost range found in literature is quite substantial. In a literature overview, Van den Brink (2003) concludes that additional costs for hydrogen-powered vehicles might be 20 to 30% higher than for conventional vehicle technology. The HyWays project (2007) mentions additional costs of anywhere up to 1500 euros, compared to those for conventional vehicles, after mass production has started. HyWays, furthermore, states that the uncertainty in cumulative costs between positive and unfavourable circumstances for hydrogen-powered vehicles can increase by as much as by a factor of ten (HyWays, 2007).

There are alternatives to storing hydrogen on board. One of these would be a vehicle with an on-board reformer that can convert gasoline, ethanol, and methanol into hydrogen with efficiencies of up to 77% (Bowers *et al*., 2006). This would require the availability of sufficient amounts of biofuels (see below). However, it should be noted that all major companies have abandoned this approach because the technology is very complicated.

Hydrogen

Hydrogen is a potentially carbon-free energy carrier. There are several ways of producing hydrogen, and the chain emissions strongly depend on the chosen feedstock and production process. Currently, production of hydrogen from Natural Gas (by Steam Methane Reforming, SMR) seems the most affordable option, and, if combined with CCS, can lead to a reduction in total emissions of about 80%. At present, the chemical industry already produces hydrogen by means of SMR. It should be noted that it is much easier to capture CO_2 in the hydrogen production process than during electric power generation because the CO_2 is at high partial pressure (Keith and Farrel, 2003).

In the longer run, there are alternative methods of producing hydrogen. It can be extracted from coal by gasification combined with CCS. Similarly, biomass gasification can be a source of hydrogen; a promising option for the future but not yet demonstrated on a large scale. Note that that use of biomass as feedstock in this process, is in competition with other biomass feedstock uses, notably co-firing in power plants for electricity production and production of second generation biofuels.

If hydrogen would be produced by electrolysis using renewable energy, this would result in a zero-emission fuel (including the chain emissions) for vehicles. With the latest technology, hydrogen production from electrolysis can be achieved at a maximum efficiency of about 75%. Subsequently, hydrogen is converted back to electricity, in the vehicle, with a lower efficiency. Therefore, this method is rather inefficient, compared to battery-powered electric vehicle, which has electricity from the power grid stored in a battery that subsequently powers the car with an overall efficiency of 85 to 90%.

There are several options for delivering hydrogen to fuel stations, including: through pipelines; by trucks in (cryogenic) liquefied form or under high pressure; locally by extraction from natural gas; or by means of electrolysis. Although hydrogen production is fairly simple – it is a gas with a low heating value and a low boiling point – it is inherently expensive to transport, store and distribute. These are strong disadvantages for a transportation fuel (Keith and Farrel, 2003).

Internal Combustion Engine Vehicles with advanced biofuels

Internal Combustion Engine Vehicles

Several studies have indicated that advanced technologies can improve the efficiency of ICE vehicles by up to 50% at increasing, but still reasonable costs, compared to total vehicle costs (Passier *et al*, 2008). However, it is highly unlikely that further progress in conventional car technologies, including optimisation of ICE, hybridisation, weight reduction, improvement of tyres and aerodynamics, could improve the efficiency of cars by more than 50%. If this level of reduction would be pursued rather than higher reductions of 65 to 95%, a difficult and uncertain transition towards new fuels and vehicle technologies might be avoidable.

However, in this scenario, the availability of oil may become a bottleneck in the long run. It would be interesting to examine the effects of continued use of fossil fuels, for example, extracted from tar sands, or liquid fuels from coal, on the long-term potential for CO_2 reduction in the transport sector. This is identified here as a topic for further research. Biofuels would be another possibility. This is discussed below.

Advanced biofuels
Since advanced second-generation biofuels commonly use low-grade material as feedstock (e.g. wood and residual materials, straw and other agricultural residues), they generate significantly less fuel-food competition. Also, their average greenhouse gas emission reductions are significantly better than those of current, first-generation biofuels (Edwards *etal*., 2006). Reports on the emission reduction potential of biofuels are not unequivocal, however. Some studies say that advanced biofuels made from residues and woody materials (Fischer Tropsch and HTU diesel) could reduce the CO_2 eq emissions of a conventional car by between 60 and 100% (Annema *et al*., 2005). Other studies report that there is little difference in the energy production per hectare, between current and advanced future biofuels (Eickhout *et al*., 2008). The overall potential of biofuels, in the long term, is limited. The OECD and IEA estimate the realistic global average market share of biofuels, in the long term, to be at 13% (IEA, 2006; OECD, 2007). Given the increased discussion on sustainability issues, production of current first generation biofuels is increasing at a lower rate than previously expected, whereas production of advanced second generation biofuels has not yet reached the commercial phase and large scale production is not expected before around 2020.

An important barrier for both current and advanced biofuels, is setting up clear sustainability criteria. Even if there is agreement on criteria, the certification schemes raise some serious questions about the effects and effectiveness. The OECD (2007) puts it as follows:

> First, *'enforcement and chain-of-custody control could prove to be an enormous challenge, as recent experiences with the certification of wood products has shown. Second, the effectiveness of certification could be undermined by displacement of biofuel products. As long as certification is not a multilateral requirement but conducted on a country-by-country basis, it will merely lead to a segmentation of the market, not to a reduction of unsustainable practices. Third, without a uniform certification scheme exporters will face increasing costs and bureaucratic complexity. A final limitation is that certification schemes do not easily capture knock-on effects on agricultural markets.'*

Thus, there are doubts that biofuels will contribute significantly to long-term CO_2 reductions in the transport sector. Biofuels may, however, be effectively applied in niche markets, such as long-haul freight transport (see Section 3.3).

Conclusions on the three scenarios for passenger cars
Apart from the scenario-specific barriers already addressed, there are some general barriers to the large-scale introduction and exploitation of FCEVs an BEVs:

- Chicken-and-egg problem: an important aspect of the introduction of new fuels and vehicle technologies is the chicken-and-egg problem between the fuel and vehicle availability. Without sufficient demand, there is no incentive for the fuel industry to make specific fuels available 'locally', and as long as those new fuels are not readily available everywhere, people will not buy the vehicles that drive on them (which will hold-off the car industry from investing in the production of hydrogen-powered vehicles). For electric vehicles the chicken-and-egg problem may be less problematic. If more electric vehicles would be used as business cars, it would become profitable, and sufficiently attractive to stimulate the required infrastructural expansion (Hanschke, 2009). The chicken-and-egg problem does not apply to advanced biofuels, since these can be applied in conventional vehicles with minor modifications.
- Air quality benefits: An argument often used for illustrating the benefits of electric and fuel-cell vehicles is their zero emissions. Although it is true that hydrogen-powered and electric vehicles emit no air pollutants, the relative gain compared to conventional cars with advanced after-treatment systems, which will become available in the near future, is very limited (Rijkeboer *et al*., 2003).
- Government income: Another important aspect, associated with the transition towards new fuels, could be government income from fuel levies and car taxes. In the Netherlands, fuel levies constitute approximately 30% (diesel) to 70% (gasoline) of the pump price. Over 10% of the total tax income, for the Netherlands, comes from fuel levies and car taxes. Production and introduction of clean fuels and energy efficient vehicles could be encouraged if these fuels were to be exempted from tax. However, this would result in substantial tax income reductions. To prevent budget deficits, these tax losses would have to be compensated by tax increases in other areas. Imposing fuel levies on new fuel types simular to conventional fuels would reduce the speed of introduction.

3.2.2 Driving efficiency
There is relatively little information available on the potential of driving efficiency, in the long term. The King Review provides an estimate for the impact of consumer choices, such as vehicle use (including 'eco-driving') and vehicle purchase decisions (King, 2007). The King Review assesses the energy reduction potential at 5 to 25% in the year 2030, but does not give a quantitative assessment for 2050. This could include, for example, creating incentives for consumers to purchase the most energy-efficient vehicles within the available classes.

There may also be technical options for increased driving efficiency through so-called Intelligent Transport Systems (ITS). In an automated motorway system, for example, specially equipped cars could travel along a lane, or set of lanes, as a convoy under computer control. This would allow for close following distances, which, in turn, would result in less drag and a reduction in fuel consumption. Emission reductions between 5 and 25% are mentioned in literature (Browland, 1997; TNO, 2008a). Translating this to the national level, a reduction of 10 to 15% would be possible. It should be noted that automated vehicle guidance systems also substantially increase infrastructure capacity. This will result in improved travel times and in reliability of the motorway system. A downside would be that these benefits could induce additional mobility, which would partly cancel out the CO_2 reduction benefits.

3.2.3 Distance travelled
Reducing the (increase in the) amount of kilometres travelled would also be an option for 2050 and beyond. It should be noted, however, that the potential for emission reductions diminishes significantly if very clean fuels and vehicles enter the market. If the transition towards advanced fuels and vehicles would be successful, the environmental benefits of and need for measures which reduce distances travelled would be reduced. However, there still might be accessibility benefits. If the transition were to be less successful, these measures could prove to be valuable back-up instruments.

Road pricing
The effects of road pricing are robust. Road-pricing schemes could reduce kilometres and, consequently, emissions by approximately 15%, by 2020 (see Section 4.4). This measure is robust, since the same reduction in kilometres is also likely to be feasible in the longer term, although this depends on more fundamental changes (e.g. ITS, telecommuting) taking place within the transport system. If these changes would lead to increased road capacity, this might cause rebound effects (more mobility), thus reducing the effectiveness of road pricing.

Spatial planning
Analysis by the Netherlands Environmental Assessment Agency in 2007 showed that preventing urban sprawl and intensified urbanisation has positive effects on the transport system (PBL, 2007). If combined with new housing projects around train stations there could be a small reduction in the overall distance travelled by car (approximately 2%). Although more rigorous spatial planning might increase this potential somewhat, the effectiveness is likely to remain small.

Mobility management
Soft measures, such as telecommuting or car sharing, if properly designed, could reduce the amount of kilometres by up to 10% (see Section 4.4). These effects are robust and not likely to change much in the long term. Of course, there will be some overlap with other, similar measures, such as road pricing.

3.3 Heavy-duty road vehicles

Heavy-duty vehicles can be divided into long-haul trucks, distribution trucks and buses. Reducing emissions from road freight is particularly challenging, since transport volumes increase, in all scenarios, up to 2050 (by 5 to 100%). Emission reductions of 65 to 95% very well may be beyond the limits of this transport mode without more drastic measures being taken, such as transport volume control.

3.3.1 Vehicle efficiency
Vehicle efficiency improvements of up to 15 to 30% for heavy-duty freight vehicles are feasible, in the long run, according to TNO (2008b), Lensink and De Wilde (2007), and Hanschke *et al.* (2009). This potential is particularly difficult to realise for long-haul freight vehicles. Since they are generally operated at constant speeds and power, vehicle hybrid technologies are not effective (since the saving potential is based on reducing energy losses at transient loads). Moreover, since these vehicles usually travel over large distances, electricity and hydrogen are not very suitable because of their storage capacity problems in combination with driving radius and the time required for recharging or refuelling.

For buses and smaller freight vehicles operating in urban areas, hybrid technology can be a feasible option. Potential emission reductions of 25 to 55% are being mentioned in literature (CE, 2008a; Passier *et al.*, 2008). There are also examples of hydrogen-powered buses being operated in several European cities (CUTE). This CUTE programme, which is funded by the European Commission, will see the operation of 47 hydrogen-powered buses in regular public transport service in 10 cities, on three continents. There seems to be no reason why other freight vehicles of similar weight and used under comparable driving conditions could not also be fuel-cell vehicles, in the future. If the hydrogen is low-carbon or zero-carbon, the emission reduction potential for these vehicles may be much higher, although additional information on the subject should be gathered.

3.3.2 Fuel efficiency
For shorter distances, hydrogen-powered freight transport might be an option. However, it seems that for long-haul freight, the only viable option for emission reduction may be biodiesel. It should be examined if it would be efficient to set specific targets for biofuel use for this segment of the transport sector. Biodiesel used for these vehicles would have to be low-carbon or zero-carbon (well-to-wheel) to achieve emission reductions in the range of 65 to 95%.

The fuel efficiency of light trucks and buses operating in urban areas might be increased further by the utilisation of biofuels.

3.3.3 Driving efficiency and distance travelled
The additional emission reduction potential of road pricing for heavy-duty transport modes is quite limited. Kilometre charges would probably be added to product prices in freight transport, and not directly affect emissions from the transport sector.

There are indications that improvements in the logistic chain may increase distribution efficiency and, hence, shorten the distances travelled. In theory, it would also be possible to reduce the average haul distance, or at least moderate its rate of increase, by reconfiguring production and distribution systems, sourcing products from local suppliers and finding shorter routes between points of loading and unloading. Analysis of energy consumption and greenhouse gas emissions in the production of a range of foodstuffs has illustrated how it can be environmentally beneficial to source some products from distant locations where production is more energy efficient (McKinnon, 2007). Very little information is generally available on the geographical structure of supply chains, and it is too early to determine the CO_2 reduction potential, at this time. More research on this subject is recommended.

Longer and heavier vehicles might increase transport efficiency and, consequently, be an option for reducing CO_2 emissions by 15 to 20% (CE, 2008a).

3.4 Aviation

Although the information found was limited, emission reductions of 70% per passenger kilometre in aviation do not seem impossible over the next 50 years, provided that technological and operational developments are fully pursued. This should also include a possible switch towards low-carbon fuels. However, given the expected substantial growth of the aviation sector, it will not be able to substantially reduce its current emission levels.

3.4.1 Vehicle and fuel efficiency

In the aviation sector, there is much focus on fuel efficiency, as fuel costs correspond with a substantial part of the operating cost. Although every new aircraft type is more fuel efficient, the average fuel efficiency (worldwide) will improve only slowly, because the economic and technical lifespan of aircrafts exceeds 20 years.

A possible low-carbon alternative to jet fuel is hydrogen. However, large-scale use of hydrogen as jet fuel, before 2050, is considered unlikely. Hydrogen as jet fuel will require vast changes in infrastructure and aircraft design. Another important aspect that should also be included in the evaluation of a transition towards hydrogen-powered jet aircraft, is the effect of water vapour emissions at high altitudes. Hydrogen vapour is a greenhouse gas itself, and effects of emissions at high altitudes might negatively impact radiative forcing. Further research is needed on this subject.

The utilisation of (large shares of) biofuels in jet aircraft is also an option. Some examples of the use of biofuels in aeroplanes already exist (see wikipedia.org).

Although there do not seem to be too many technological barriers for the utilisation of biofuels in aeroplanes (apart from the tight safety requirements and operational circumstances), again, substantial CO_2 reductions depend on the availability of sufficient low-carbon biofuels. As was mentioned above, the potential of biofuels for the transport sector might be limited because of the potentially limited production capacity.

3.4.2 'Driving efficiency' and distance travelled

Improved operational practices and optimised aircraft deployment may have the potential for reducing fuel consumption by 2 to 6%. This can be achieved through measures, such as better flight planning, speed management, selection of appropriate aircraft, equipment weight reduction, and taxiing with one engine shut down after landing. Improved air traffic control, resulting in more direct routes and reduced delays, could reduce overall fuel consumption by 6 to 12% (SA, 2008). In effect, CO_2 emissions could be reduced by approximately 10% compared to business-as-usual.

3.5 Other transport modes

Although information is scarce, emission reductions of 65 to 95% are likely to be too ambitious for the following modes of transport.

3.5.1 Mode of transport and fuel efficiency

Inland shipping

Inland navigation (transport with ships via inland waters) is generally more fuel efficient than trucking. Fuel consumption per tonne-kilometre of inland navigation is roughly one third of that of road transport. Nevertheless, vessels used for inland shipping could be made even more efficient through various modifications to ship designs. Several options are available for reducing the power needed to propel a ship, such as improved hull form, air lubrication, and improved propellers, such as the Z-drive (www.cleanestship.eu). For specific purposes, diesel-electric propulsion may be a viable option. All Electric Ships (AES) can save significantly on energy, particularly when they have a non-linear engine load factor. Fuel-cell utilisation in inland shipping has been evaluated and found to be complicated because of the large quantities of hydrogen needed and the limited on-board storage space (De Wilde *et al.,* 2006). The utilisation of advanced biofuels, however, may very well be a feasible option for inland shipping (Passier *et al*., 2008).

Overall CO_2 emission reductions of 30 to 40% are considered to be possible. A barrier to realise this potential is the limited incentive for innovation in this transport mode, because of specifics of this sector (many individual ship owners, small profit margins, and ships' longevity) (Passier *et al*, 2008). Additional research is recommended.

Sea ships

Sea ships are even more fuel efficient than inland vessels, because of their generally (much) larger size. Sea ships sail over large distances and, therefore, require that large amounts of energy are stored on board. Thus, storage of sufficient amounts of electricity or hydrogen are likely to form an important barrier. A more in-depth literature review is recommended to reveal information on the utilisation of advanced drivetrain technology, or the utilisation of biofuels in sea ships. Although utilisation of biofuels is not likely to be hampered by technological barriers, the total fuel demand by the world fleet (about 375 million tonnes per year) is probably too large to meet with biofuels alone.

Off-road vehicles

These vehicles are used mostly for construction and agricultural purposes. The bulk of them use diesel engines. No information was found on the utilisation of alternative drive trains in these vehicles, although, at first glance, there do not seem to be insurmountable barriers to apply diesel-electric propulsion, as with light trucks and ships. Further research is recommended, however.

Rail transport

Emissions from electrified rail transport are attributed to the energy sector, according to IPCC bookkeeping rules. The limited share of diesel trains (mostly freight transport) in overall rail transport is less energy efficient than its electrified counterpart. Replacing diesel trains with electric trains can reduce CO_2 emissions from this sector, particularly, when the electricity produced is low carbon.

3.5.2 Driving efficiency and distance travelled

For the above modes of transport, any information on emission reduction potential linked to driving efficiency was only found for inland shipping. Installing a device that actively controls the ships' speed according to current, depth, and presence of locks, can reduce energy use by 4 to 12% (Passier *et al.*, 2008). However, the potential for emission reduction through driving efficiency and distance travelled is expected to be limited for shipping, off-road machinery and rail transport.

3.6 Trading schemes

There are also options for long-term emission reduction that cannot be adequately placed into the King categories used above. These options concern overarching measures that include trading mechanisms, and do not specifically aim to reduce emissions from a certain transport category. They are, in principle, applicable to all transport modes. This section will briefly comment on two different trading schemes: EU ETS and the 'Low-Carbon Fuel Standard'(LCFS) which has been adopted in California. It should be noted that there are more possibilities for introducing trading mechanisms into the transport sector to reduce emissions. The following two examples illustrate the basic principle.

3.6.1 Transport in the EU ETS

The transport sector could be included in the EU ETS, or a separate trading system could be set up. From a literature review, Kampman *et al.* (2008) conclude that '*emission trading could be an effective means to reduce CO_2 emissions in the road transport sector, if an upstream trading system is chosen, i.e. a system in which the oil companies are the trading entities. It is also concluded that a CO_2 tax on fuel may have the same effect as an emission trading system, at lower cost for the society, provided that the tax rate is set at the appropriate level. This measure may, however, face political difficulties.*'

Kampman *et al*. (2008), particularly, see potential in a combination of emission trading for the transport sector and CO_2 emission legislation. The former will create incentives for fuel companies to develop advanced low-carbon fuels. The latter will stimulate innovation (as discussed above) in vehicle technology.

The effectiveness depends on the cap that is enforced. The stricter the cap, the more effective trading will be, as long as close and proper monitoring of the actual CO_2 emissions of participants is carried out. Including the transport sector in the EU ETS will result in additional costs for this sector (from CO_2 reducing measures or purchasing the required emission rights), which are expected to be passed on to consumers at the pump[1]. Given the high taxation on fuel, the relative price increase is limited from a consumer perspective, and will not result in substantially lower fuel consumption. Combined with the fact that transport measures are relatively expensive (compared to measures in other sectors), and hence are expected to be higher than the CO_2 price, there will be a very limited incentive to improve the overall energy efficiency in the transport sector via technological improvements. Based on this reasoning, emission trading schemes are not the best instrument to create innovation in the transport sector.

However, trading schemes do have the clear advantage, namely, that they avoid the risk of technology lock-in since they are generic, and the market is free to decide which technology will be pursued. Moreover, if properly organised, a trading scheme assures that, in a perfect world, the climate targets are met at the lowest possible costs, given the available options in the included sectors.

As the current scope of the EU ETS is limited to the EU, including the transport sector could have some undesired side effects. Inclusion will result in higher of the tradeable CO_2 permits, which, in turn, increases the risk of companies moving outside of the EU ETS zone. This so-called CO_2 leakage, caused by these companies moving, could be mitigated through several techniques, or by implementing a separate trading system for the transport sector, assuring that the cheapest options for the sector are chosen. Such a separate system has the disadvantage that the overall climate targets perhaps would have been achieved at lower costs, if cheaper options from outside the transport sector were used.

3.6.2 CO_2 fuel standard with tradeable permits

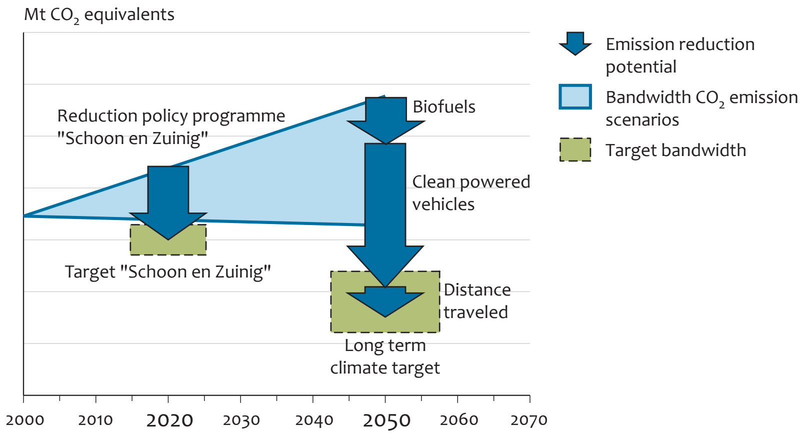
California issued a new guideline in 2007, the 'Low-Carbon Fuel Standard' (LCFS), prescribing a 10% reduction in the 'carbon intensity' (on a well-to-wheel basis) of transport fuels, by 2020.

The LCFS will use market-based mechanisms that allow providers to choose how they reduce emissions while responding to consumer demand. For example, providers may purchase more low-carbon bioethanol and blend it into petroleum products, purchase credits from electric utilities supplying low-carbon electricity to electric passenger vehicles, diversify into low-carbon hydrogen as a product, and more, including new strategies yet to be developed.

The University of California, Berkeley, analysed the technological pathways to realise the target (Farell *et al*., 2007a&b). The main conclusion was: 'On the basis of a study of a wide range of vehicle fuel options, we find a 10 percent reduction in the carbon intensity of transportation fuels by 2020 to be an ambitious but attainable target. With some vehicle and fuel combinations, a reduction of 15 percent may be possible. All of the major low-carbon fuel options to reduce GHG emissions from the transportation sector (e.g., biofuel production and electric vehicles) have technical and economic uncertainties that need further research and evaluation. However, there is a wide variety of options, of which many show great potential for lowering the global warming impact of transportation

1 It is assumed that the fuel suppliers will be the trading parties.

Feasible CO_2 emission reduction for transport **Figure 3.3**



Schematic representation of potentially feasible emission reduction for the transport sector, by 2050.

fuels. Many research and development efforts are already underway to bring these advanced technologies to market'.

The European Fuel Quality Directive also sets a reduction target (6% by 2020) for the carbon intensity of fuels sold. The main difference with the California LCFS is the absence of tradeable permits.

3.7 Summary of options for 2050

Based on the findings in the preceding sections, Figure 3.3 gives a schematic overview of the emission reduction potential in the transport sector, for the year 2050. The bandwidth of the CO_2 emissions in the four WLO scenarios (see Section 2.2) is represented by the blue triangle in this figure. The targets and feasible reductions are offset against a high-growth scenario (GE), that is, a worst-case scenario.

From this figure, it becomes clear that emission reductions of 65 to 95%, compared to 2000 levels, in the transport sector are *potentially* feasible by 2050. The bulk of the emission reduction has to come from light-duty vehicles, by means of new vehicle technologies, such as Battery Electric Vehicles (BEVs) and Fuel-Cell Electric Vehicles (FCEVs). Additional emission reduction potential (10 to 20%) may come from biofuels, and from measures aimed at reducing the distance travelled (road pricing, spatial planning and mobility management).

For heavy-duty road transport and non-road transport, the target of 65 to 95% in emission reduction is much more difficult to reach. Advanced vehicle technologies (electric and hydrogen) are not always suitable for these transport modes. For substantial, long-term emission reductions, these modes depend more strongly on the availability of low-carbon biofuels. Since the share of biofuels in overall energy consumption in transport will remain small, it may be worthwhile to reserve biofuels for these heavy-duty transport modes and not for light-duty transport where there are potentially alternative low-carbon energy sources.

Reaching long-term climate targets depends on two crucial factors:

1. The availability of new vehicle technologies;
2. The availability of low-carbon or zero-carbon fuels.

It should be noted that, in the figure, the order in which the measures are depicted influences the size of the arrow and the represented potential. Moving the arrow for distance travelled to the top of the stack would increase its size. The capital argument would be that, without clean powered vehicles and zero-carbon or low-carbon fuels, long-term targets are out of reach.

Apart from the two more technical criteria mentioned above, there is a third important criterion for long-term emission reductions of 65 to 95%:

3. Changes in travel behaviour and demand: public acceptance.

Certainly could be stated that if, by 2050, all passenger cars would be electric or hydrogen-powered vehicles, emission targets would be met. With equal certainty, one could say that if people would drive 50% fewer kilometres by tomorrow, CO_2 emissions would decrease substantially. Although the emission reduction *potential* is clear, it is not difficult to understand that getting people to indeed cut their driving distances by 50%, is far from straightforward.

Whether low-carbon or zero-carbon fuels and advanced vehicle technologies enter the market does not depend solely on their timely production or on incentives by the government to promote investments. New vehicle technologies, and the fuels that propel them, also affect travel behaviour and demand. Driving an electric or hydrogen-powered vehicle is different from a conventional vehicle, in terms of possible driving radius and refuelling conditions. The flexibility of electric passenger cars, for example, may be smaller because of relatively long 'refuelling' times. In the transition stage, consumers and companies will consider whether these changes are disadvantageous to them, compared to driving a conventional vehicle. In short, public acceptance of decarbonised transport is a very important criterion for meeting long-term climate targets.

The conclusion can be drawn that long-term climate targets are potentially within reach of the transport sector, although this will require efforts on different aspects (volume, efficiency, and low-carbon fuels). The main challenge in realising the potential emission reductions is getting the right answers to the following questions: What policies should policymakers develop to ensure this potential is realised? Are we currently moving in the right direction? Do the measures, that are currently being implemented or considered by the Dutch Government to meet 2020 targets, create an incentive for making the clean vehicles and fuels available that are needed to meet 2050 targets?

At the end of Chapter 4, an attempt has been made to answer these questions.

The medium term: 2020

4

This chapter reviews the transport measures included in the Dutch policy programme *Schoon en Zuinig* (VROM, 2007). Table 4.1 gives an overview of these measures. At the end of this chapter, an overview is given of all measures including a qualitative score based on criteria that determine the success of climate measures.

4.1 Fuel efficiency

4.1.1 Biofuels

According to IPCC reporting guidelines, replacing 1% of fossil fuels with biofuels counts as a 1% CO_2 emission reduction. The reduction potential of a 10 to 20% share of biofuels is assessed to be 2 to 6 Mt in CO_2 emissions (ECN/MNP, 2007; ECN/PBL, 2009). Considering that the Dutch transport target is a 13 to 17 Mt reduction, increasing the share of biofuels is an effective way to bring climate targets within reach.

Although these IPCC bookkeeping rules make biofuels an effective measure, the real world impact of biofuels has recently become subject of scientific debate. Topics that are debated are:

- The net energy balance and greenhouse gas emissions of the biofuels supply chain. Cultivation of biofuel feedstocks, their conversion into a liquid fuel, and the logistics in-between all require energy that leads to greenhouse gas emissions. These emissions differ greatly between different types of biofuels and their feedstocks, and even between different crop management types per biofuel feedstock. For the latter, emissions of N_2O, a strong greenhouse gas, is a critical factor due to fertiliser utilisation. This leads to a wide range in greenhouse gas emission estimates. One of the most comprehensive assessments currently available is the CONCAWE/EUCAR/JRC study (Edwards et al., 2006).
- Apart from production-chain emissions, biofuels from agricultural crops can generate greenhouse gas emissions by changes in the organic carbon content of soil, due to land-use change. This can occur directly in the field where crops are cultivated, but also indirectly. For example, corn used for ethanol that is planted on US farmland that was formerly used for growing cereals may induce soil carbon losses through the conversion of forests into arable land elsewhere in the world, to maintain food production. A well-known analysis of this effect is the study of Searchinger *et al*. (2008). However, the extent to which such effects occur depends on a multitude of uncertain developments (see also Sylvester-Bradley (2008). One of the most critical factors is whether farmers will respond to the increasing demand for crops by taking more arable land into production (possibly causing GHG emissions), or by increasing the productivity of existing cropland (with minor additional GHG emissions).
- Related to this issue is the fuel-food discussion: conventional biofuels use food crops as their feedstock. Although

Overview of transport measures in the Dutch policy programme Schoon en Zuinig **Table 4.1**

Key factor		Schoon en Zuinig
Fuel efficiency	1	Biofuels (first generation)
	2	Biofuels (second generation)
	3	CNG
Vehicle efficiency	4	CO_2 emission legislation passenger cars and vans
	5	Fiscal measures
	6	CO_2 emission reduction freight vehicles
	7	Innovation programme 'Car of the future'.
	8	Innovation in public transport
Driving efficiency	9	Public awareness campaign (eco-driving)
	10	Exploring modal shift towards energy efficient transport
Distance travelled	11	Road pricing passenger cars
	12	Road pricing freight
	13	Mobility management

Options 7, 8 and 10 are mainly research and demonstration programmes. These options are not discussed in this report, since no assessment of their effectiveness is currently available.

such demand is still relatively small compared to crop demand for food and feed (Bole and Londo, 2008), there is concern that biofuel development may lead to growing food prices and induce poverty, especially in urban areas (Gallagher *et al.,* 2008; Oxfam, 2008). Especially in developing countries, production of biofuels and their feedstocks entails both opportunities and risks, in terms of economic development and social welfare. A crucial factor appears to be local farmers' security of land tenure (Cotula *et al*., 2008), an area in which several developing countries have particularly bad track records.

Although, as discussed in Section 3.2, advanced (second generation) technologies are more favorable because they use non-food crops which also have a higher energy density, biofuels remain a much debated option. Nevertheless, in December 2008, the European Parliament agreed on an adjusted Renewables Directive, in which all Member States commit to a 10% target for renewable fuels in transport in 2020. Although electricity, biogas and hydrogen are also eligible to be used for achieving this target, it is expected that a large share will be in biofuels. The Dutch Minister of the Environment has reduced the 2010 target for biofuels from 5.75 to 4%.

The real-world emission reduction and sustainability of biofuels cannot be directly controlled by the Dutch Government, as the majority of biofuels or their feedstocks are produced outside of the Netherlands. Although the Dutch Government could decide to adopt more stringent sustainability criteria – if it feels that European agreement on those criteria takes too much time – it is questionable whether these specific criteria, coming from a rather small country, would be fully acknowledged by biofuel-producing countries.

Another possible criticism against stimulating first generation biofuels is that, by strongly increasing their share before 2020, a technology lock-in could be created which, in turn, could hamper the introduction of advanced or second-generation biofuels. Particularly for diesel substitutes, the conversion process for second-generation biofuels (e.g. the Fischer Tropsch process) differs greatly from that used for current biodiesel (Van den Brink *et al,* 2004b).

4.1.2 CNG (Compressed Natural Gas)

Compressed Natural Gas (CNG) is an alternative transport fuel, which is frequently discussed in the Netherlands. It is also included in the *Schoon en Zuinig* policy programme. The contribution of CNG to the climate targets for 2020 is small; if 10% of new passenger cars and 20% of new buses would use CNG by 2020, this would mean a reduction of only 0,35 Mt in CO_2 emissions (Hanschke *et al,* 2009).

One of the main reasons for this limited climate benefit is that CNG cars emit only 15 to 20% less CO_2 than comparable petrol cars, and only 5% less than those on diesel. Furthermore, CNG cars are not more fuel efficient than petrol cars, they just use a fuel with lower carbon content. CNG does have a significant advantage in improving local air quality, due to lower emissions of PM_{10} and NO_x. However, advanced exhaust control in conventional vehicles can have the same effect (Rijkeboer *et al*., 2003), and the importance of the air quality benefit, therefore, would diminish after 2014, when the new European standard for emission limits for passenger cars, Euro 6, will enter into force (Verbeek, 2008).

Because of a number of barriers, large market shares are not expected for CNG:

- There is no adequate refuelling infrastructure in place within the Netherlands, although it is currently growing, as a result of government subsidies.
- The costs for CNG vehicles are higher than for petrol cars. Although an excise tax exemption currently makes driving a CNG car relatively cheap, this could probably not be maintained if CNG would have a large market share.
- The space required for the CNG storage tanks in the car, and their added weight, the latter resulting in reduced energy efficiency.
- The limited driving radius (approximately 300 kilometres for a passenger car), and the time required for refuelling.

Using CNG in buses is a viable option for improving local air quality in urban environments, in the short to medium term. For buses, the option of providing refuelling facilities at a central location, is an added benefit.

In the long run, another pressing issue is the availability and costs of natural gas. The Netherlands is likely to become a net importer of natural gas, around 2030, and replacing an oil dependency with a dependency on natural gas, could be a disadvantage. Therefore, CNG is often regarded a transition option, a predecessor for more sustainable, long-term options, such as green gas or hydrogen.

CNG as predecessor of biogas

The prospects for green gas in the transport sector depend on a couple of uncertainties. First, the potential depends on the availability of sustainable biomass, see also the discussion in the previous section. This is most appropriate for biogas from digestion of residues, which could potentially, only meet around 10% of the fuel demand of Dutch road transport (Platform Nieuw Gas, 2007). Using biogas for electricity generation or for heating and cooking in the built environment, is also possible. The other source of green gas is SNG (synthetic natural gas), generated from biomass gasification. However, this process requires woody biomass, which can also be used for producing Fischer Tropsch (FT) diesel, a second generation biofuel that does not require a separate refuelling infrastructure or adjusted vehicle. For both SNG and FT diesel, the biomass required should be grown sustainably and should not compete with food supplies.

CNG as predecessor of hydrogen in fuel-cell cars

There are a number of important differences between the production and distribution of natural gas and hydrogen:

- CNG, locally compressed natural gas, is stored in special cylinders until needed. These cylinders cannot be used for storing hydrogen, because a higher pressure is needed for the latter. Moreover, hydrogen has special corrosion properties, which should be taken into account for all materials used.
- A high cost component for a CNG refuelling station is the natural gas compressor, and just like the cylinders, it cannot be used for hydrogen because of the different properties.

- Storage of the two energy carriers within the car requires different cylinders under different pressure. Given the differences in pressure, refuelling equipment is also not interchangeable.
- The distribution infrastructure is different for both fuels, and because of their different corrosion properties, the natural gas infrastructure could not be reused for hydrogen.
- For both fuels, vehicle technology is different. CNG cars require a modified internal combustion engine, while hydrogen should be used in fuel-cell cars for optimum energy efficiency gains.
- For the consumer, fuelling a CNG car is different from fuelling a fuel-cell car. Public acceptance of hydrogen is therefore not likely to benefit much from CNG on this aspect.

In conclusion can be stated that, in the long run, CNG is not a predecessor of hydrogen, because there are too many differences between the gases and their infrastructures. CNG could be regarded a predecessor of green gas, but only if the transition towards green gas in the transport sector is prioritised over other alternatives.

4.2 Vehicle efficiency

4.2.1 CO_2 emission legislation for cars and vans

The European Commission is drawing up a proposal, announced in January 2007, for reducing CO_2 emissions from new passenger cars sold in the EU. Currently, new passenger cars emit approximately 160 grams of CO_2 per kilometre. The proposal aims to find ways of making car manufacturers reduce this to a level of 130 g/km, by 2012. Other technical measures and increased use of biofuels should lead to a further reduction of 10 g/km.

The environmental commission of the European Parliament has further announced that an emission limit of 95 g/km should be strived for, by 2020. There are currently no detailed proposals or plans for vans. The European Parliament and the EU countries have recently agreed to delay the full introduction until 2015 (ENDS, 2008).

The effect of a standard at 130 g/km is assessed at approximately 2.5 Mt (assuming the target would be reached by 2015). If an emission limit of 95 g/km would be reached by 2020, this would lead to an emission reduction of approximately 4 Mt. An additional emission reduction of 0.5 Mt would be attainable, if comparable limits were set for vans (ECN/PBL, 2009). Considering that the Dutch transport target is 13 to 17 Mt reduction of CO_2, emission legislation for cars and vans would be an effective way of bringing climate targets within reach.

The measure design provides the opportunity for car manufacturers to choose the most cost-effective option for meeting the required emission standard, whether that be through conventional or new technologies, and, therefore, does not encourage the use of specific breakthrough technologies. This reduces the risk of lock-in of technologies which, over time, might prove to be less successful. However, this type of emission legislation does lead to gradual lowering of car emissions, and, if a single target is set, efforts to meet this target might divert attention away from options that are (much) more ambitious. Because of the gradual character of this legislation, its innovative incentive might be limited if no additional incentives are included for the development of cars that are even more energy efficient than the limit requires (Jeeninga *et al*., 2008).

There is one important uncertainty, or dilemma, intertwined with the CO_2 emission legislation for passenger cars and vans (and also other vehicles), which is the determination of how tight the emission limits could be. There is a limit to the technical efficiency gains that can be reached before the year 2020. A very strict limit (probably from about 100 g/km downward) might force car manufacturers to 'downsize' their cars. As will be explained further in Section 5.5, 'downsizing' will lead to a loss in consumer surplus, or in welfare losses that cannot be properly assessed at this moment.

A downside of this measure, from the Dutch perspective, is their limited government control. Agreeing to a legislative framework for the 130 g/km target and possibly stricter emission limits in the future, requires cooperation and agreement on a European level between the European Commission, car manufacturers and car producing countries. The Netherlands can certainly play a role in negotiations and in setting the agenda, but the chances of success are nonetheless smaller than they would be if the Netherlands could set their own CO_2 limits for all cars sold nationally. However, such a national measure most likely would not be allowed by the European Commission, since it may lead to market distortions.

Currently, because of a relatively large share of petrol cars, the average new-bought Dutch car has a CO_2 emission factor of 160 g/km, whereas the EU average is 156 g/km. The European legislative framework is set up in such a way that car makers are required to lower the CO_2 emission from the average car sold *in Europe* to a level of 130 g/km. There is thus no guarantee that the average car sold in the Netherlands will not have a higher emission factor. To assure that the car mix in the Netherlands improves, as well, complementary policies might be needed; for example, the implementation of fiscal and other measures aimed specifically at Dutch car owners/users.

4.2.2 Efficiency improvement freight transport

The *Schoon en Zuinig* policy programme announces an exploration of policies for improving the efficiency of freight transport. In the assessments of the policy programme, no effect could be attributed to this programme yet (ECN/MNP, 2007; ECN/PBL, 2009). Recently, some studies have been published providing information on the emission reduction potential of freight transport. A report by the European Commission revealed several options for efficiency gains in road freight transport. The overall CO_2 reduction from several identified measures was assessed to be limited (Maunsell, 2008). Lensink and De Wilde (2007) estimated higher potentials. Their literature review shows many cost-effective options, as CO_2 emissions are strongly correlated with fuel consumption. Overall, they found a CO_2 emission reduction potential for the road transport sector, in the Netherlands, of 5 to 10%, by 2015. By 2015, because of their relatively short lifespan, most of current road freight vehicles will be replaced. The reduction potential for 2030 was estimated at 15% for road freight transport in the Netherlands. Lensink and De Wilde (2007) were careful to point out that measures, needed for reaching these reductions, should have a short payback time (no more than three years), because of the short lifespan of freight vehicles.

TNO (2008b) also reviewed the potential for CO_2 emission reduction for heavy-duty vehicles. Their estimate was that an emission reduction of 15% would be feasible for new vehicles, by 2020. They assumed that 7.5% would occur autonomously, regardless of policy. Additional reduction would be possible through a combination of measures that limit the need for mechanical energy and improve drive train and motor efficiency. Examples of such measures are weight reduction, reduced rolling resistance, improved transmission, and the inclusion of hybrid elements.

All in all, efficiency gains in freight transport seem possible and effective. One of the instruments for achieving this could be CO_2 emission legislation for freight. This would be a flexible measure, not prescribing the type of technology used by manufacturers. The measure would ensure that, given the emission limit, manufacturers can choose the most cost-effective option – either through improving conventional technologies, or by developing new ones. As with passenger cars and vans, setting CO_2 limits requires cooperation and agreement, on a European level. It is a process that could only partly be influenced by the Dutch Government.

Another practical issue pointed out by TNO (2008b) is the need for real-world, type-approval tests for freight vehicles, to properly monitor the progress. The European Commission is currently working on such a type approval.

Apart from these options, there are others that may be effective in reducing emissions. One option would be to introduce the Japanese so-called 'TOP runner programme' in Europe. Instead of setting a minimum efficiency today, this programme searches for the most efficient model on the market and then stipulates that the efficiency of this top runner model should become the standard within a certain number of years. Since manufacturers are themselves responsible for calculating the energy efficiency of their vehicles, there is a certain risk that reported efficiency does not compare fully with real-world efficiency (TNO, 2008b).

4.2.3 Fiscal measures

Privately owned cars

Since large and heavy cars emit more CO_2 per kilometre than lighter and smaller cars do, differentiating the purchase tax of passenger cars based on their CO_2 emission level could potentially reduce emissions. Purchase tax differentiation (PTD) was first introduced in the Netherlands in 2002, for a period of 1 year, and was reintroduced in July 2006. In February 2008, the measure was further intensified.

The Dutch PTD is currently linked to the energy labels of cars. These labels relate to vehicle size, and they (including bonuses and penalties) are awarded per vehicle size group. In this system, small cars could receive a G label and a penalty (of up to € 1600), while large cars receive an A label with a bonus (of up to € 1400). Under real-world conditions, however, the large car would emit more CO_2 per kilometre than the small one. Recently, the Dutch parliament passed a resolution to alter this relative system into a system based on absolute emission levels. The expectation is that this would be more effective for reducing CO_2 emissions.

An assessment was made of the effects of a Purchase Tax Differentiation strategy that is linked to the absolute CO_2 emissions from cars (CE, 2008b). It concludes that the effects of an absolute system and a relative system (as is currently in place in the Netherlands) are comparable, since the CO_2 reduction which is achieved when people buy smaller cars, would be compensated by the lower incentive to buy the vehicle with the lowest CO_2 emissions within its class.

The analyses, in part, were based on simulations using the car-ownership model DYNAMO (MuConsult, 2006), and reported an effect of 0.3 to 0.5 Mt, by 2020, which would almost entirely be the result of a shift towards the purchase of smaller cars. CE was careful to point out that these are first rough estimates and that additional research would be required for a better understanding of the real-world effects. The Purchase Tax Differentiation measure should be qualified as moderately effective.

Company cars

The market for privately owned cars is a little over 40% of all new cars sold in the Netherlands (Kieboom and Geurs, 2009). The remaining 60% are company cars. These car drivers are not faced with the purchase tax, therefore, the incentive of a Purchase Tax Differentiation will be limited to private car owners. There is another fiscal measure for stimulating the sale of more energy-efficient company cars. About 75% of all company-car drivers use this car privately, as well. Since this private travel is taxed by the Dutch Government, a taxation related to CO_2 emission could result in a more energy-efficient company car fleet provided employees are free to choose car makes and models. There is a comparable system in the United Kingdom, which, for company cars, has resulted in a drop in average CO_2 emissions per kilometre of 15 g/km. Part of this effect can be attributed to a shift toward more diesel cars (HM Revenue and Customs, 2006).

For the Dutch case, CE looked into the effects of taxation on private use of company cars, related to CO_2 emissions. They assessed a possible CO_2 reduction of 0.2 to 0.45 Mt by 2020 (CE, 2008b). This measure should be qualified as moderately effective. It is an efficient measure, however, since it creates incentives to drive more energy-efficient cars in a significant segment of passenger-car transport, where such incentives were previously absent. It adheres to the principle 'the polluter pays'.

4.3 Driving efficiency

4.3.1 Public awareness campaigns (eco-driving)

The Dutch climate programme includes the implementation of public-awareness campaigns which also aim to improve driving efficiency through eco-driving. The main elements of eco-driving are early gear changing or driving at low RPMs, maintaining a steady speed, smooth deceleration and acceleration, anticipating traffic flow and frequently monitoring tyre pressure. It is a driving style suited to modern engine technology. It also reduces fuel consumption (and thus greenhouse gas emissions) and accidents. Research has shown that fuel savings ranging from 5 to 25% are feasible (Van de Burgwal and Gense, 2002).

It should be noted that the Dutch eco-driving programme *Het Nieuwe Rijden* ('the new driving') was already included in the baseline emission projections. The programme currently consists of four stages, two of which were included in the baseline emission projection. The assigned emission reduction of the first two stages is 0.8 Mt CO_2 (Van Dril and Elzenga, 2005), in all scenarios. The Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) has estimated that the next stages could deliver another 0.7 Mt (SenterNovem, 2005). Assessing the additional effect of the next stages is very challenging, since little information is available on the lasting effects of the programme.

4.4 Distance travelled

4.4.1 Road pricing

The Dutch Government is currently planning to implement a nation-wide kilometre charge for road transport. The measure entails abolishment of the fixed purchase tax and road tax for passenger cars, and replacing these with a charge per kilometre. At the same time, a kilometre charge is introduced for freight vehicles. The target is to start implementation in 2011 or 2012, although it is currently uncertain whether this deadline can be met. The main goal of the kilometre charge is to improve accessibility and reduce congestion, but there are also environmental benefits. These benefits could increase if the pricing scheme were to be designed specifically to stimulate the sale of fuel-efficient cars.

The emission reduction through kilometre charging was assessed at 2 to 3 Mt (ECN/MNP, 2007; ECN/PBL, 2009). In 2008 a study was carried out that examined different levels of the variability in these fixed taxes (Besseling *et al.,* 2008). The study examined the effects of complete variability in the road tax and different levels of variability in the purchase tax (0%, 25%, 50%, 75%, 80%, 90%, 100%). The study showed that a CO_2 reduction of up to 15%, compared to 2020 emission levels, would be possible. In that case, the emission reduction could become as high as 3 Mt. This would largely be attributed to passenger cars. The reduction in kilometres in road freight would be limited.

Road pricing is considered to be an effective measure. Apart from environmental benefits, kilometre charging could also lead to net social benefits, according to a Social Cost Benefit Analysis. Variability in road tax alone would already substantially increase the environmental benefits and travel-time benefits, mainly due to reduced congestion.

Furthermore, road pricing would be a robust measure, since the effects would apply to the present and to the future, regardless of new vehicle technologies that might enter the market.

4.4.2 Mobility management and telecommuting

The Dutch policy programme also promotes telecommuting. For telecommuting, the assumption is often that working at home reduces the number of kilometres that an individual travels, consequently resulting in a reduction in CO_2 emissions. However, for someone working at home, one or more days a week, the commuting time on the other days is of less importance, than to someone that commutes every day. As a consequence, telecommuters could decide to buy homes further away from their workplace, thereby nullifying (to a certain extent) the reduction in kilometres that result from partly working at home (KiM, 2007). Quantitative research on travel behaviour of telecommuters shows mixed results. Some studies show a significant reduction in work-related travel, total number of trips and total distance travelled. Other studies, however, suggest that ICT use at home and telecommuting, in particular, may lead to an increase in non-work related trips and activities, and that telecommuting is unlikely to reduce travel significantly (Kwan *et al*., 2007). According to a recent British study, it would be possible to achieve a reduction in national traffic levels of about 11% with so-called 'soft' factor interventions, 'smarter choice' measures, or 'mobility management' tools (Cairns *et al*., 2008). Moreover, the authors concluded that these measures represent relatively good value for money with benefit cost ratios in excess of 10:1. Car sharing, telecommuting and teleconferencing are examples of potentially effective measures.

In a review of several studies, the Dutch Ministry of Transport concluded that telecommuting could be used as an instrument for tackling congestion, rather than for reducing overall mobility. The impact on overall mobility, according to this review, would be a reduction of 0.5 to 1.5% (V&W, 2003). Similar research in the United States shows that an overall reduction in vehicle miles travelled is of the order of 0.8% or less (Choo *et al.*, 2005).

All in all, it seems that mobility management could be a worthwhile consideration, since it could potentially be effective. It is also clear from the above that fulfilling this potential is very challenging. If successfully implemented, mobility management would be a flexible measure, since it does not interfere with measures aimed at the other three key factors (fuel, vehicle and driving efficiency).

4.5 Qualitative assessment of options for 2020

This section presents a qualitative assessment of the options for 2020, to the Dutch Government for meeting the 2020 targets. A number of criteria were used to assess the measures:

1. Effectiveness: substantial CO_2 emission reduction in absolute terms, compared to emission projection;
2. Cost-effectiveness: low costs relative to other measures (in other sectors) including welfare costs from a national perspective;
3. Flexibility: not aimed at a single technique or technology. Flexible measures reduce the chance of lock-in;

Qualitative assessment of transport climate options for 2020

Table 4.2

		Effectiveness	Cost-effectiveness	Flexibility	Technological innovation	Secondary benefits	Sustainability issues	EU/NL
		2020		2050				
	Fuel efficiency							
1	Biofuels (first generation)	++	0	-	-	0	--	NL
2	Biofuels (second generation)	0 [a]	0	-	-	0	+/- [b]	EU
3	CNG	0	-	-	-	+	0	NL
	Vehicle efficiency							
4	CO_2 limit passenger cars and vans	++	+/? [c]	+	+	0	0	EU
5	Fiscal measures	+	++	+	0	0	0	NL
6	Efficiency improvement freight	+	+	+	+	0	0	EU
	Driver efficiency							
9	Public awareness (eco-driving)	0	+	++	0	0	0	NL
	Distance travelled							
11	Road pricing passenger cars	++	++	++	0	++	0	NL
12	Road pricing freight	0	0	++	+	+	0	NL
13	Mobility management	0	++	++	0	++	0	NL

a) Second generation biofuels have the potential to be very effective beyond 2020. These advanced biofuels will not enter the market in large quantities before 2020
b) The impact on sustainability issues could be positive if adequate sustainability criteria are formulated and maintained. If not, a negative impact would be possible;
c) CO_2 emission legislation is cost effective to the point where it leads to downsizing. Beyond that point, substantial welfare losses may occur and costs would be difficult to estimate

4. Technological innovation incentive: long-term emission reduction requires new technologies (vehicles and fuels);
5. Secondary benefits: improvements in air quality, noise pollution, and traffic safety;
6. Sustainability issues: no, or limited, negative trade-offs in biodiversity, food prices, energy security;
7. EU/NL: this criterion states whether the measure is national (NL) or European. If a measure has the label 'EU' this means that the Netherlands will have difficulty to influence its effectiveness.

Each measure receives a qualitative score, per criterion:

++	Very high	--	Very poor
+	Substantial	-	Limited
0	Negligible	?	Unknown

The first two criteria only look at 2020 targets. A measure is deemed (cost-)effective if it would bring the Dutch climate targets for 2020 within reach, at relatively low costs. The last four criteria have an overarching focus and give an impression of a measure's viability for 2020, *in relation to* 2050 targets.

The scores on all criteria combined, give an impression of a measure's viability to meet 2020 targets *and* long-term climate targets. A measure might score positively only on the first two criteria. This would mean that it is a viable measure for achieving the 2020 climate targets, but will add little to bring long-term targets within reach. Other measures might score poorly on the first two criteria, but positively on the last four. Such measures would be viable for the long term, but add little to bringing medium-term targets within reach. Measures that score positively on all criteria are viable measures for meeting both the 2020 targets *and* the long-term climate targets. Such measures are robust.

The results of the qualitative analysis is given in Table 4.2 It should be acknowledged that the qualifications given here are open for debate. They were based on expert judgment following from the findings in previous chapters and the literature review carried out for this report.

What conclusions can be drawn from Table 4.2?

Reduction potential of '*Schoon en Zuinig*' relies on three important measures

In the current Dutch policy programme, three measures have the largest contributions to the desired emission reduction: biofuels (first generation), CO_2 emission legislation for passenger cars and vans, and road pricing. Two other measures have a substantial effect. This means that quite a few measures (see Table 4.1) do not add substantially to meeting the 2020 targets. This raises the question whether much effort should be put into these measures (from the perspective of climate targets), and whether other measures should be added, in case medium-term climate targets are difficult to reach.

However, this depends on the robustness of these measures. Are they no-regret? It could be argued that measures to increase the share of second-generation biofuels could be robust, as long as sustainability criteria are taken into account. As was mentioned in Chapter 3, biofuels may be a viable option for long-haul road freight transport. Eco-driving programmes are no-regret, although real-world effects probably will remain difficult to estimate, and new vehicle technology, such as hybridisation, will reduce eco-driving's future potential. In the longer run, fiscal measures (purchase tax differentiation and other tax schemes to induce the sale of energy-efficient vehicles) are no longer available, because of the introduction of road pricing (which entails abolishment of vehicle taxes). However, a road-pricing scheme can also promote the sales of fuel-efficient cars. Road pricing for freight transport is not effective from a climate point of view, but has other benefits (reducing congestion and improving air quality). The long-term robustness of CNG can be questioned in light of the limited climate benefits, unless CNG is gradually replaced by green gas.

A 10 to 20% share of biofuels, by 2020, is not efficient

One of the three effective measures (first-generation biofuels) scores poorly on the last four criteria. This means that it would be effective for meeting the *Schoon en Zuinig* targets, but not for meeting long-term climate targets. The Dutch policy programme depends quite strongly on first-generation biofuels, and considers a 10 to 20% share, by 2020. It is questionable whether a share of 10% would be attainable under sustainability criteria currently considered. Moreover, adopting high shares of biofuels before 2020 may hold a lock-in risk, particularly for biodiesel, where the production process greatly differs between first and second generation fuels. Advanced biofuels will not enter the market in large quantities before 2020. These fuels have a better potential for reducing CO_2 emissions and meeting sustainability criteria. Current policies (EU Renewables Directive) do contain incentives for increasing the share of advanced biofuels.

Meeting Dutch targets for 2020 depends highly on success of European climate policy

Setting up sustainability requirements for biofuels and introducing CO_2 emission legalisation for passenger cars and vans is primarily coordinated on a European level, and can only partly be influenced by the Dutch Government. This stresses the need for strong presence and substantive contributions from policymakers in Brussels. Road pricing is one of the most effective measures the Dutch Government can take by itself.

Additional measures with focus on clean fuel and vehicle technology can increase effectiveness of 'Schoon en Zuinig' to meet long-term targets

A number of interesting aspects of the Dutch policy programme follow from Table 4.2. The most apparent conclusion is that very few measures contribute to reaching the fuel and vehicle criteria, identified in Chapter 3, which are needed to reach emission reduction levels of 65 to 95%. Most measures have no or only a limited effect on bringing about a shift towards the production of low-carbon or zero-carbon fuels and new vehicle technologies. There are two measures that score positively on either of the main criteria: second-generation biofuels and CO_2 emission legislation. The first has the potential for increasing the share of low-carbon fuels. It should be noted, however, that due to the limited biomass potential, the long-term effectiveness is expected to be limited (see Chapter 3). CO_2 emission legislation has potential to promote the production of battery electric vehicles only if a shift towards hybrids and plug-in hybrids would be required to meet the targets. As was mentioned above, the incremental improvements associated with the CO_2 legislation approach, have the risk of limiting innovative incentives (Jeeninga *et al*., 2008).

Chicken-and-egg problem requires attention

Another important conclusion that does not follow directly from Table 4.2 is the chicken-and-egg problem, e.g. the fact that a new fuel and its refuelling infrastructure should be introduced simultaneously. The measures that score positively on the criterion for technological innovation score positively on either clean vehicle technology (CO_2 emission legislation) or clean fuels (second-generation biofuels). This is not all that surprising; fuels and vehicles are produced by different sectors (energy production and transport). It does imply, however, that coordination of the efforts made in both sectors is needed to overcome the chicken-and-egg problem, which could seriously hamper the transition. For electric vehicles, the classical chicken-and-egg problem might be less problematic, although a number of barriers could still remain (see Section 3.2.1).

There are robust measures

Some technical measures that can be applied in current vehicle technology, as well as future vehicle technologies, are also robust or no-regret. Examples are energy efficient tyres, weight reduction, aerodynamics, tyre pressure indicators, and energy-efficient air conditioners.

Long-term targets require different measures

It seems that, to achieve long-term climate targets for transport, very different measures are needed on top of those currently included in the Dutch policy programme. The measures that contribute substantially to the emission reduction target create little incentive for the development of vehicle technology and low-carbon fuels, which are needed for the long term.

For this purpose, a number of Dutch research programmes (called innovation platforms) have been installed. These programmes investigate the possibilities for sustainable transport and alternative fuels, beyond 2020. The effects of these programmes were not subjected to the analysis carried out in this report. But even if we assume that these platforms will be very successful in introducing advanced vehicles and zero-carbon fuels, beyond 2020, this does not alter the conclusion that measures currently adopted have little synergy with long-term climate targets. We recommend that additional research is carried out to examine the effectiveness of the Dutch innovation strategy. This effectiveness is crucial for the success of long-term mitigation strategies.

5

Barriers for successful climate policy in transport

From reading Chapters 3 and 4, it might seem that the argument is made for policymakers to 'simply' increase their efforts, and that additional measures will lead to additional emission reductions and solve long-term transition issues. It should be pointed out, however, that it may not be that straightforward. This chapter identifies six typical barriers, in the transport sector, to illustrate that an additional effort in climate policy may not easily lead to the desired results. These barriers are:

- The European context
- Life-cycle analysis and carbon leakage
- Inelastic transport demand
- Slow vehicle stock replacement
- Welfare costs and indirect effects
- Real-world effects versus testing

5.1 The European context

The Netherlands is one of 27 EU Member States. Much of environmental policy is designed and implemented by the European Commission. Each Member State has the opportunity to contribute ideas, and an active role increases the chance for national ideas to be included. Nevertheless, the final directive will be a consensus agreement, in which the most ambitious targets are likely to be softened. For the transport sector, the Dutch Government has set an emission reduction target comparable to that of the European Commission (see Chapter 2): 13 to 17 Mt versus -16% CO_2 eq reduction, by 2020. Also, the Dutch policy programme relies quite heavily on measures which require a certain level of international agreement (CO_2 emission legislation for cars, vans and freight vehicles, and biofuels, with respect to sustainability criteria).

This illustrates a dilemma for the Dutch Government in terms of their climate programme. On the one hand they want to set ambitious targets, following from the good intention that for long-term climate targets immediate and substantial action is required. These ambitions, on the other hand, are difficult to fulfil, due to the fact that measures should be initiated on a European level to be the most (cost-)effective.

To elaborate on this, consider CO_2 emission limits for passenger cars. The attainability of the Dutch 2020 emission reduction target depends, to a large extent, on the CO_2 emission limit that will be negotiated for the long run. The Dutch Minister of the Environment initially pleaded for an emission target of 80 g/km by 2020. However, other EU ministers argued this was too ambitious, after which the Dutch Minister adjusted the ambition downwards to 95 g/km (De Stem, 2008).

The recent agreement between EU governments and the European Parliament on the CO_2 limit for new passenger cars also specifies the longer-term emission target of 95g/km, by 2020 (ENDS, 2008). The commission is expected to propose more precise details for meeting this target, including how it will be shared among car makers, in a review of the legislation in early 2013. Since the ambitious 95 g/km target will be reviewed, it is not final yet, and provides no guarantee for the Dutch Government. Another uncertainty is that even if the target would be agreed upon, manufacturers might fail to meet it, by 2020. This increases the risk of not meeting national targets.

One might suggest that the Dutch Government could then simply follow their own course, not allowing cars on the Dutch market that emit more than a certain emission limit. The European Commission, however, would probably not allow an individual Member State to take such a measure, since this might result in market distortions. Moreover, if cars meet the standards according to EU environmental laws, they cannot be banned by certain Member States. It would however be possible to increase taxes of less energy efficient cars.

The limited scope does not only apply to technical improvements in vehicle efficiency. Ensuring that biofuels, of which most would have to be imported, are sustainable, would require sustainability criteria which are agreed upon on a European or, even better, global scale. If a single country, such as the Netherlands, would decide to formulate more stringent sustainability criteria, it remains to be seen whether sufficient biofuel producers would wish to adhere to these criteria if they could sell their product elsewhere, without

Indicative fuel-price elasticities for passenger-car use and fuel consumption — Table 5.1

	Short term (1 year)	Long term (5-10 years)
Kilometres	-0.1 to -0.2	-0.25 to -0.5
Fuel consumption	-0.25 to -0.35	-0.6 to -0.8

having to do so. If producers would decide to supply the Dutch market, their production costs would likely be higher, resulting in higher biofuel prices.

In short, the potential for emission reduction in the Netherlands, to a large extent, depends on international cooperation, a process on which it has only limited influence. If the target would be a fixed emission reduction requirement, by a fixed target year, it would be 'riskier' to aim for measures that require such cooperation, than for national measures.

5.2 Life-cycle analysis and carbon leakage

Although not specific to the transport sector, life-cycle analysis is an important aspect to consider when assessing the CO_2 reduction potential of measures. Not including life-cycle emissions from goods that aim to reduce CO_2 emissions, might induce carbon leakage. Carbon leakage occurs when CO_2 emission reductions within the Netherlands cause additional CO_2 emissions outside of the Netherlands. On a national level, this could also occur between different sectors. Currently, this is already an issue for diesel cars (see text box *Diesel crunch*).

Carbon leakage is also associated with the use of biofuels. If biofuels are produced outside of the Netherlands, but used within national borders, IPCC reporting guidelines state that emissions from biofuel use are zero. If in other words, 10% of conventional fuels is replaced by imported biofuels, then CO_2 emissions also decrease by (approximately) 10%. For a small country such as the Netherlands, which will have to import most of its biofuels, this means that, from an emission reduction perspective, there is an incentive to increase the use of biofuels, particularly when there is a chance of not meeting emission targets. The carbon leakage from foreign production and distribution, however, should be considered when balancing different CO_2 mitigation alternatives.

In a 'perfect world', all climate-change related policies should include CO_2 leakage on a global scale, to avoid counting 'false' reductions. This, however, is not straightforward. Determining the well-to-wheel fuel efficiency of biofuels, for example, may prove to be difficult. To determine the precise CO_2 efficiency of a fuel, production and distribution needs to be closely monitored. For global large-scale production of biofuels, such monitoring may be very costly and difficult to manage. Monitoring CO_2 emission during the production of vehicles, or assessing these emissions for new vehicle technologies is equally challenging.

This creates a dilemma for the Dutch Government (and others). National targets or climate targets can be very effectively achieved with a measure such as biofuel. Looking beyond the national borders, however, makes the use of biofuels and perhaps other measures much less suitable.

It should be noted, that following the scientific debate on biofuels (see Section 4.1.1), the Dutch Government decided to reduce the 2010 biofuel target to a level of 4%, instead of 5.75%. As part of their search for sustainability criteria, set to increase the viability of biofuels, the Dutch Government and the European Commission are also looking for solutions to overcome carbon leakage.

5.3 Inelastic transport demand

5.3.1 Passenger-car demand

Mobility is highly valued. The flexibility of the car seems unequivocally superior to any other transport mode, and any (government) action to discourage passenger-car use by, for example, increasing taxes, is likely to find substantial public resistance. The limited willingness of people to cut down on their mobility can be illustrated by viewing price elasticities. An elasticity of -1 means that a price increase of 1% will lead to a reduction of demand with 1%. Geilenkirchen *et al*. (2009 in preparation) give a recent overview of elasticities for the transport sector (see Table 5.1).

Table 5.1 shows that fuel-price elasticity for fuel consumption is higher than for mobility demand (kilometres driven). It seems that car owners would rather consume less fuel and maintain there level of mobility. This consequently leads to the purchase of more energy-efficient cars in the medium to long term.

The inelastic demand for car mobility can be partly traced back to the relatively high taxation of passenger-car mobility. Nearly half of the diesel price and more than two thirds of the petrol price consists of taxes. Any additional taxes, therefore, would lead to a relatively small increase in total costs and, as a result, have a limited effect.

If the government would directly limit the amount of kilometres people would be allowed to drive, this would be an effective way of reducing emissions. However, many people would probably object to such a measure, since it would limit their freedom of choice. Also, passenger-car transport, to a large extent, is an integral part of social life (family visits, holidays, recreational trips, etc.).

5.3.2 Freight transport

For freight transport, elasticities are also fairly small. A price increase of 1% will lead to a decrease of 0.6 to 0.9% of ton-kilometres via road. Approximately 0.4 to 0.5% of this decrease is the result of substitution by other modes of transport (rail, inland shipping) (Geilenkirchen *et al*., 2009 in preparation).

For freight haulers, approximately 30 to 40% of transport costs are related to fuel. Freight haulers, therefore, are inclined to save as much fuel as they can, since this will give them a competitive advantage. Road freight vehicles have

Text box : Diesel crunch

Diesel vehicles have a better fuel economy and, therefore, lower CO_2 emissions per kilometre, than petrol vehicles. Over the last two decades, the performance of diesel engines in terms of acceleration and engine power has increased substantially. Present diesel engines have a performance that is comparable to petrol engines. In addition, diesel engines offer better fuel economy and a high torque. Over the past years, the number of diesel-powered vehicles in road transportation, in Europe, has increased substantially and, consequently, so has the demand for diesel fuel.

While petrol demand in the United States is growing, in Europe it has actually declined, since 2000 (See Figure 5.1),at an average of 2.1 percent per year, and the diesel demand has increased by 2.0 percent.

The increasing demand for diesel within the European Union means that there is intense competition for this fuel on the world market. This phenomenon is often called the 'diesel crunch'. In the short term, additional increased demand for diesel from the Asian developing countries imposes further strains. In Asia, diesel demand has grown at the rate of 2.7 percent, since 2000.

During the distillation process, refineries produce a full spectrum of refinery products, including light distillates, such as naphtha, LPG and petrol, as well as middle distillates, especially road diesel and jet fuel. The product mix from the basic refinery process of distillation, cannot be changed. Depending on the crude type, 35 to 60% in residuals remain after distillation. The residual stream can be converted into lighter products, which, to some extent, enables changing the product mix and to increasing the diesel production relative to the other refinery products. This diesel increase can be achieved by: (1) increasing the ratio of hydrocracking (diesel production) over cat cracking (petrol production); (2) conversion of heavy residues combined with hydro-treatment; and by (3) producing it from natural gas (gas to liquids). Volumes of this production route are still low, but gradually increasing. An alternative solution would be the production of more biodiesel.

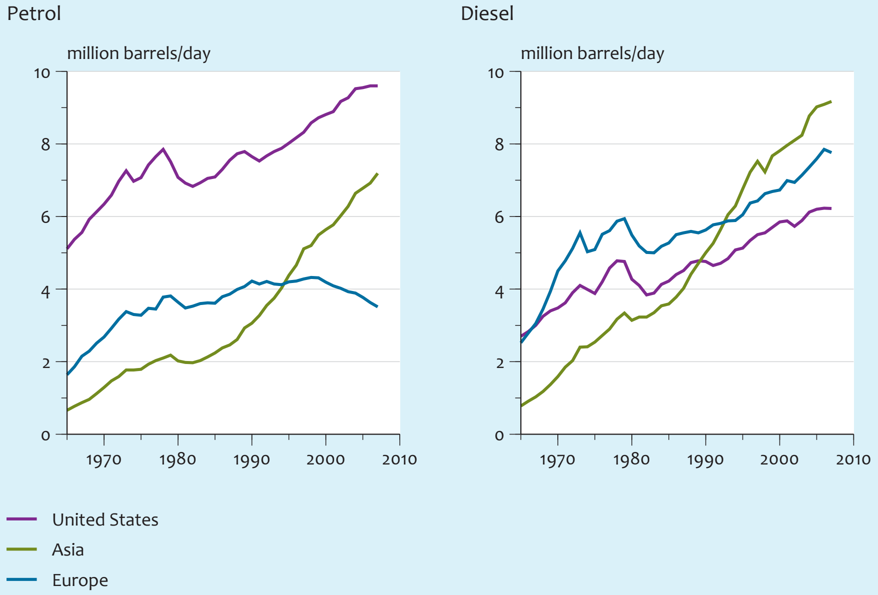
The European refinery sector has already stretched the diesel production substantially, because of the diesel shortages in Europe. A further increase of the diesel production, thus reducing CO_2 emissions in the transport sector by increasing the share of fuel-efficient diesel cars, can only be achieved at a loss in efficiency and an increase in CO_2 emissions from the refineries.

Some basic calculations with the ECN refinery model Serum indicates that the production of additional diesel by secondary conversion processes, will require about twice as much in energy, and related CO_2 emissions, compared to the primary distillation process.

This means that a CO_2-saving effect on the road through further dieselisation of vehicles, can be substantially reduced by the increase in refinery emissions, related to the secondary refinery processes for the additional diesel demand. A demand which could not be met by primary conversion processes. Roughly estimated, taking the additional refinery emissions into account, about half of the CO_2 reduction from, increased dieselisation would remain,.

Petrol and diesel demand

Figure 5.1



Trends in petrol and diesel demand in the United States, Europe, and Asia (1995-2004). Source: BP, Statistical Review of World Energy, June 2005 become much more energy efficient over the last decennia. Increasing fuel prices through levies, therefore, has limited additional potential for further increasing fuel efficiency in freight transport. Moreover, additional transport costs are simply passed on to consumers. Since transport cost are only a small portion of product costs, increased freighting costs would lead to only a limited price increase of goods. Since this would hardly affect the demand for these transported goods, there would be little incentive for freight haulers to increase their energy efficiency.

5.4 Slow vehicle stock replacement

The introduction of clean and efficient technologies does not immediately lead to significant environmental benefits. Clearly not everyone buys a new car every year. The penetration of clean technologies, therefore, takes time. The existing stocks of passenger cars need about 12 years before it is replaced. For freight vehicles, this is roughly six years. If an energy-efficient passenger car would be introduced on the market, in 2015, the total emission reduction potential would take up to approximately 12 years, to be at its maximum, assuming the technology gets a 100% share in the new sales from the moment it is introduced onto the market (which is unlikely, because of, for example, higher costs and infrastructural barriers).

This illustrates that delays in agreements on CO_2 emission limits for passenger cars (see Section 4.2) will have an effect on the emission reduction potential, by 2020, as it will result in a lower share of more fuel-efficient cars in passenger car stocks of 2020. Especially new technologies with relatively high additional costs will need extra time to attain their maximum potential.

5.5 Welfare costs and indirect effects

Assessing costs of measures is common practice. Costs give information on the effectiveness of measures and give policymakers the opportunity of choosing only those measures that enable them to meet policy targets, at the lowest possible costs.

However, calculating the costs of a measure is not straightforward. A basic problem is that there is not one single definition of costs. A comparison of cost effectiveness of different CO_2 abatement measures in the transport sector showed that different *perspectives* are used in policy evaluation, and that the *scope of costs* that are integrated in a cost effectiveness assessment, vary (CE, 2007).

Perspective

Particularly in the transport sector, assessment of the cost effectiveness of an abatement measure from the perspective of the end user, can differ greatly from that of society as a whole. Measures which, for example, are designed to reduce vehicle fuel consumption also affect the flow of tax revenue from road users to government. In the Netherlands, fuel tax and other taxes make up a substantial proportion of total transport costs. From the perspective of the end user, savings on these costs definitely count and should be included, while from the perspective of society as a whole, they should be excluded. Climate policy measures that reduce the aggregate annual mileage of all vehicles, are another example of measures that have a substantial impact on the overall welfare of society, because they also reduce other externalities (such as air pollution and noise), which should be included from society's perspective but not from that of the end user. This shows the importance of always pointing out from which perspective costs of a measure are assessed.

Scope of costs

In the Dutch Ministry of the Environment's 'Environmental Costing Methodology Manual', drawn up in 1994 and updated in 1998, it is recommended that the cost effectiveness of environmental measures be calculated on the basis of direct expenditures only (VROM, 1998). Although this is the preferred method, the manual also allows for including additional cost information (for example, indirect costs). Applying the preferred methodology may lead to counterintuitive results of certain measures. A fuel tax increase, for example, would result in a negative cost effectiveness (see text box *A fuel tax increase makes everybody happy, or does it?*).

A growing number of reports are appearing, in both policy and research circles, in which a comprehensive welfare-economic analysis is recommended. In this kind of analysis, not only direct expenditures are regarded as costs, but also losses in welfare associated with enforced behavioural change, the indirect costs of the measure, and additional externalities, that is, other than those the measure is designed to reduce. There are two extra 'cost items' in a welfare-economic analysis that lead to yielding very different results (CE, 2007a):

1. Particularly in the transport sector, climate measures also have a substantial impact on other externalities. Measures to cut vehicle fuel consumption reduce not only CO_2 emissions, but also, for example, those of NO_x and particulates. Measures that reduce aggregate annual mileage also reduce noise, congestion and the number of road traffic injuries and deaths. Including these externalities in calculations of cost effectiveness is of major influence on results.
2. Measures to reduce aggregate annual mileage or fuel consumption often mean an enforced change in behaviour: without the measure, people would have driven more kilometres or bought a different type of car. If only direct expenditures are included, these kinds of measures would involve only profits and no losses. After all, those choosing not to make a particular journey or to buy a smaller car are left with more money in their pocket. In a welfare-economic analysis, the conclusions may look rather different. Not being able to do something that one would have preferred to do constitutes a loss in welfare. This loss can be expressed in monetary terms. Because of the already relatively high taxes on car ownership and use (fuel tax), additional cuts in transport volumes will be associated with high welfare costs to society.

Resume on costs

An illustrative example of the impact of different cost methodologies, which gives the cost-effectiveness of a fuel price increase of one euro cent per litre, is shown in Table 5.2.

Cost-effectiveness of a petrol price increase of € 0,01 per litre

Table 5.2

Cost-effectiveness per avoided litre	Direct expenditures	Welfare analysis
End user	- € 625 / ton CO_2	€ 2 / ton CO_2
Society	- € 208 / ton CO_2	€ 417 / tonCO_2

Cost-effectiveness of a petrol price increase of € 0,01 per litre, using different costing methodologies. Source: CE, 2007a

For more detailed information on why the cost-effectiveness differs so much, we refer to CE (2007a). For now, it suffices to state that cost methodologies play a crucial role in determining which measures are 'best' to implement, in order to meet policy targets. It is important not to mix different methodologies when comparing measures. This would also include synchronising cost methodologies across sectors, since comparing transport measures with measures in other sectors is only possible when using the same cost methodologies.

Although including welfare costs in a cost-effectiveness analysis may produce more viable results for the example of fuel tax increase in transport, many indirect costs are difficult to monetise. How much money, for example, do we 'save' as a society, when a measure results in one less traffic fatality? How much does it cost when a measure results in more noise nuisance to people? What do we gain when the emissions of particulates are reduced by one million kg per year, and how do we monetise this?

These questions are very difficult to answer. And because determining (welfare) costs is challenging, it presents a barrier for determining the effectiveness of transport climate policy, and the attainability of transport climate targets.

5.6 Real world versus testing

Differences between testing and real-world conditions make monitoring efficiency improvements less reliable. For passenger cars, for example, the monitored CO_2 emission per kilometre is currently around 160 g/km. This figure, however, is based on the ECE drive cycle that, in terms of levels of acceleration and deceleration, is not representative of real-

Text box: A fuel tax increase makes everybody happy, or does it?

Imagine the government would decide to increase fuel taxes as a measure for reducing CO_2 emissions. This would obviously lead to a higher fuel price if crude oil prices remain unchanged. A higher price would lead to less consumption. The relation between changes in price and demand is shown in the price elasticity. In literature, a price elasticity of -0.1 to -0.5 is found for fuel-price increases (Geilenkirchen et al., 2009 in preparation). This means that a fuel-price increase of 1% would lead to a decrease in fuel consumption of 0.1 tot 0.5%. If the 'Environmental Costing Methodology' (VROM, 1998) is used, then several direct expenditures (costs and benefits) are identified for both the government and the consumer. Fuel consumption decreases, so tax revenues for the government do, too. However, each litre of fuel sold will give the government extra tax income because of the higher taxes. Since the price elasticity on fuel consumption is inelastic (the decrease of fuel consumption is smaller than the increase in price), there is a net increase in tax income. These benefits will flow back to society as public funds. Additional taxes collected, therefore, should be seen as a mere redistribution of income, not affecting the overall income of society.

The average consumer will respond to this measure by reducing his or her fuel consumption. We specifically say average here because some consumers may choose to maintain their level of mobility and simply pay more for fuel than they used to, whereas other consumers might decide that the fuel price increase makes car mobility too expensive for them, and travel by train from then on. On average, however, there will be less fuel consumed. Based on the price elasticity mentioned above, the consumer will in general not save money as the price increase offsets the resulting volume reduction (i.e. the price elasticity is smaller than 1).

Based on the same elasticity, it can be concluded that the government will have additional tax income, which will be spent on public goods that benefit society as a whole. Combined with the lower fuel consumption (implying less CO_2 emissions), the result from a national perspective would be that this CO_2 abatement measure leads to net benefits for society as a whole. So, along this line of reasoning, a very large tax increase would be a very effective measure. This makes everybody happy, or does it?

Clearly, something has been overlooked here. If saving money by reducing fuel consumption would seem beneficial to car drivers, than they need not wait on a fuel tax increase. All car drivers could decide, right at this moment, to sell their cars and save lots of money on fuel. Thus, there is another cost component that is overlooked here. The fact that people decide to buy fuel means that the amount of mobility they can enjoy from it represents a value to them that is (at least) equal to the amount they spend on fuel. If a fuel tax increase 'forces' them to drive less kilometres, then the value that these kilometres represent disappears. This loss of value is also referred to as welfare loss. This example points out that although the 'Environmental Costing Methodology' provides valuable information, interpreting the results can be precarious. If such welfare losses could be included into the cost calculation, somehow, the cost effectiveness would be quite different and, in fact, no longer be negative.

world driving. Moreover, all electrical appliances, including air conditioning, are turned off during a test cycle, and the cars are equipped with special small testing tyres that require less energy to be propelled. Literature gives values of 10 to 20% for corrections on testing conditions, to estimate real-world emissions (Zacharidias, 2005; TNO *et al*., 2006; Burgwal and Gense, 2003). This means that the monitored 160 g/km is really somewhere between 175 and 195 g/km.

Moreover, the difference between testing and real-world emissions is expected to increase in the future (Zachariadis, 2005). An increase in the share of hybrids is one of the reasons for possibly larger discrepancies (Hoen *et al*., 2006). Hybrid vehicles are particularly energy efficient in urban driving conditions with dynamic traffic flows. On motorways however, the energy benefits are much smaller. There are indications from real-world tests by the Dutch Automobile organisation (ANWB), that hybrid passenger cars are 25 to 45% less energy efficient than the ECE test suggests (ANWB, 2004a; ANWB, 2004b). A reason for this might be that the share of urban driving in the ECE test is relatively large, compared to the real-world situation. If, for hybrids, the difference in emissions between real world and testing, is in fact larger than for conventional vehicle technologies, then the effects of CO_2 emission regulation for passenger cars might be overestimated if a substantial increase in hybrids is a condition to meet the CO_2 standards.

Another aspect, not included in a testing environment, is driving behaviour. Eco-driving is thought to be able to achieve substantial fuel savings. Experiments have revealed fuel savings of 5 to 25% (Burgwal and Gense, 2002). It is, however, nearly impossible to estimate real world efficiency gains. People would have to be monitored before and after improving their driving efficiency. Moreover, the monitoring would have to be maintained, since the eco-driving rules might gradually be forgotten. Such monitoring systems are unheard of today, and although it is likely that fuel savings are possible in this domain, assessing the real-world gains is currently not possible. In addition, new vehicle technology, such as hybridisation, will reduce the future saving potential of eco-driving.

The difference between real world and testing emissions illustrates that it may be difficult to determine the effectiveness of climate policy for transport.

6

Main conclusions and discussion

The preceding chapters have revealed the challenges for the transport sector in achieving medium-term and long-term climate targets. This final chapter consists of two sections. The first section gives an overview of the main conclusions. The second section suggests some topics for discussion and further research.

6.1 Main conclusions

Long term (2050)

- The transport sector faces the major challenge of meeting the long-term targets for reducing emissions by 65 to 95%[1], compared to 2000 levels, especially since the transport volume is expected to double between 2000 and 2050. The question whether the transport sector should contribute more, equally, or less than other sectors is discussed in Section 6.2.
- Further incremental improvements of conventional ICE technologies could result in maximum efficiency gains of about 50%, and could only lead to a stabilisation of transport emissions. This makes clear that a long-term emission reduction target of 65 to 95% cannot be achieved by improving conventional technology alone.
- However, several options are available to decarbonise transport to a large extent. There are three crucial conditions for achieving CO_2 reductions of 65 to 95% in the transport sector:
  1. Substantial changes in travel behaviour, travel demand and public acceptance;
  2. Availability of zero-carbon or low-carbon fuels;
  3. Availability of advanced vehicle technology.
- The first criterion is difficult to control, but nonetheless crucial for the success of climate policy. Much attention in the debate on mitigation of climate change in the transport sector is given to the technical potential of future technology. The question of how this potential could be fulfilled highly depends on public acceptance and the willingness of people to alter their mobility behaviour.
- The long-term emission reduction potential for the Netherlands also highly depends on successful international cooperation and agreement, and on the resulting effectiveness of European climate policies, as these will be essential for the introduction of advanced vehicle technologies and low-carbon fuels.
- For passenger car transport, both electricity and hydrogen in combination with Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs) have the potential for achieving a long-term CO_2 reduction target in the range of 65 to 95%. Only if combinations of low-carbon energy carriers and advanced vehicle technology become available, at a large scale, could this target be met. Therefore, policymakers should adopt an integrated approach for the energy and transport sectors, aimed at facilitating a smooth transition towards the production of both advanced vehicles and a low-carbon energy carrier.
- Both the electricity and hydrogen pathway for passenger car transport are characterised by long development and implementation trajectories. No 'winning' technology can be identified with certainty at this time, although the classic chicken-and-egg problem associated with the availability of the fuel infrastructure seems much more prominent for the hydrogen route. Decarbonisation of both technologies relies heavily on Carbon Capture and Storage (CCS) and/or massive implementation of renewable energy sources, especially wind.
- The large-scale utilisation of electricity and hydrogen in transport could be complemented by second generation biomass, applied in vehicles with advanced internal combustion engines. The total amount of biofuels available will be limited, however. For this reason, biofuels should preferably be applied in subsectors or niches where they could not be (easily) substituted with electricity or hydrogen; for example, in long-haul trucking and shipping.
- The technical potential for emission reduction in road freight transport, aviation and shipping, is smaller than in passenger car transport. To achieve emission reductions of 65 to 95%, these modes depend stronger on biofuels and changes in mobility demand and behaviour (improved logistics in freight transport and reduced air travel). Relatively little information is available for these modes and additional research is recommended.

Short term (2020)

- There is limited additional technical potential, on top of the measures proposed in the Dutch policy programme *Schoon*

1 The global CO_2 reduction targets for 2050, required to keep the temperature increase below two degrees as advised by Stern (2006) and IPCC(2008), respectively, results in emission reductions of 65 -95% for the transport sector; taking into account the expected doubling in transport volume (King 2007), and assuming an equal share of emission reductions over all sectors.

en Zuinig, to reduce transport emissions. This is partly explained by the fact that replacing vehicle stocks takes time, thereby limiting the pace at which clean technologies can penetrate the vehicle fleet. Furthermore, it is observed that the additional reduction potential relates to mobility behaviour or vehicle choice, imposing additional barriers with respect to public and political acceptance.

- About 70% of the Dutch 2020 CO_2 reduction target for transport requires measures that depend on successful international cooperation and agreement (e.g. sustainability criteria for biofuels, and CO_2 emission limits for vehicles). Meeting Dutch targets for 2020, thus, highly depends on the success of European climate policy. This stresses the need for a strong presence and substantive contributions by Dutch policymakers in Brussels.
- The Dutch Government considers a 10 to 20% share of biofuels, by 2020. If supported by policies to assure sustainability criteria, the Netherlands could obtain the 10 to 20% share by imports and national production. However, with a global view, it is questionable whether a high share of biofuels in transport is attainable under sustainability criteria currently considered. In addition, adopting large shares of biofuels, before 2020 may hold a lock-in risk, particularly for biodiesel, where the production process greatly differs between first and second generation fuels (see also Section 3.2). Advanced biofuels will not enter the market in large quantities before 2020. These fuels have a better potential for reducing CO_2 emissions and meeting sustainability criteria. The long-term robustness of CNG can also be questioned in light of the limited climate benefits, unless CNG is gradually replaced by green gas.

Synergy 2020 and 2050 policies

- To achieve the challenging long-term climate targets for transport, very different measures are needed in addition to those currently included in the Dutch policy programme. The reason for this is that most measures that contribute substantially to the emission reduction target for 2020 create little incentive for the development of vehicle technology and low-carbon fuels, which are needed in the long term.
- Given the ambitious emission reduction targets, and the limited potential of short-term measures, it is clear that these measures should be complemented by parallel investments in 'new' technologies (electricity, hydrogen) which, in the future, could be decarbonised to a large extent. Since these new technologies have long lead and implementation times, a policy strategy should be developed today, which ensures that experience is gained and cost reductions are induced. This strategy should allow for these new technologies to reach their full implementation, in time. At a limited total budget, overinvestment in incremental improvement of conventional technologies may hinder investments in, and success of long-term, essential alternatives.
- CO_2 emission legislation for passenger cars and vans is a measure that *does* create a certain synergy with long-term targets. The synergy may come from increased shares of hybrids and plug-in hybrid vehicles, which require similar battery technology as future Battery Electric Vehicles. Nevertheless, it is important to consider the inclusion of stronger incentives for the development of more disruptive innovative clean technologies, which are essential for reaching the ambitious, long-term targets.
- Reduction in transport demand (through, for example, road pricing and mobility management) is robust and no-regret, since it contributes to both the short-term and the long-term climate targets. Over the last decades, however, transport demand has been closely linked to economic and demographic growth, and the success of policies that aim to reduce mobility has not been equivocal.
- Some technical measures that can be applied in current vehicle technology, as well as future vehicle technologies, are also robust or no-regret. Examples are energy efficient tyres, weight reduction, aerodynamics, tyre pressure indicators, and energy-efficient air conditioners.

6.2 Topics for further discussion

In drawing up this report and formulating the conclusions, a few issues were identified that are relevant for the current discussion on transport and climate targets.

How ambitious can short-term targets be, without resulting in lock-in?

Lock-in of technologies may occur if current legislation stimulates large-scale investments in technologies that are unsuitable to meet long-term targets (e.g. first-generation biodiesel). If vested interests in first-generation biodiesel are large enough, it may result in competitive disadvantages for investors in advanced biofuels that have a better potential for meeting long-term climate targets. The lock-in of first-generation biodiesel may then result in a more difficult transition to advanced emission reduction technologies. This does not necessarily mean that stimulating the use of first-generation biofuels to limit 2020 emissions should be abolished. First-generation biofuels will reduce emissions up to 2020, and will make the policy gap between 2020 and 2050 smaller.

The problem here is that it is unknown at which level or share of first generation biofuels the benefits of the emission reductions gained through them is outweighed by a lock-in situation. Thus, there is a trade-off between benefits of early CO_2 emission reductions (in transport), before 2020, and the risk of lock-in of current technologies that are not suitable to bring long-term climate targets within reach. Overambitious targets for 2020 may increase the risk of lock-in, whereas targets that are easy to reach may make the policy gap between 2020 and 2050 undesirably large.

More research is recommended on how policy can smoothen the transition

It is also difficult, at present, to stimulate investments in specific technologies that *do* have the potential for meeting long-term targets. According to this report, it is too early to pick a winner between battery electric vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs). Choosing an obligatory share of 5% electrical vehicles, for example, also holds the risk of lock-in if, over time, the hydrogen route proves to be more viable. More generally speaking, further technology development should take place before any particular technology is selected for mass market introduction.

This suggests that climate policy should, perhaps, be flexible, and leave the decision on which technology is the best also to market actors. Emission trading is a flexible instrument that leaves the decision on the best alternative to the market. It is very unlikely, however, that trading systems will create sufficient incentive to guarantee that market parties will invest in advanced technologies. Specific policies for the long-term transition are therefore inevitable when aiming for emission reductions in the range of 65 to 95%, compared to 2000 levels.

How lock-in should be prevented, which measures result in lock-in, which advanced technologies should be promoted through policy, and to what extent, are questions that cannot be adequately addressed, at this moment. To answer these questions, the debate on climate targets, and the ways of meeting these targets, will have to be extended.

The observation is undisputed that a transition towards new fuel and vehicle technologies is needed to meet long-term climate targets for the transport sector. However, initiating and controlling this transition is a complex process, which requires international coordination and constant monitoring of technology developments, cost impacts, societal needs, and geopolitics. Here lies an important challenge for both policymakers and researchers to find strategies that facilitate this transition.

How much should the transport sector contribute to long-term climate targets?

This report has based its analysis on the assumption that the transport sector should reduce its emissions with 65 to 95% compared to 2000, the same as in other sectors. However, the question of whether this is indeed the most efficient strategy for achieving long-term climate targets, remains unanswered. Objectively defining what would be the 'most efficient strategy' is not possible, since there are different approaches in determining a fair burden sharing over sectors.

It is not uncommon in policy evaluation to establish an efficient distribution of burden sharing over sectors, based on the cost-effectiveness of measures. In such a case, the underlying assumption is that achieving targets at lowest costs (to society) is a sound principle.

Establishing burden sharing, based on lowest costs, thus, requires that the cost-effectiveness of all possible measures in all sectors are determined. With this information, a marginal cost curve could be constructed to determine a cost-efficient distribution and 'fair' share for all sectors.

Determining the cost-effectiveness of transport measures aimed to reduce CO_2 emissions, is particularly difficult. In addition to technical measures, ambitious reduction targets will also influence mobility and consumer behaviour. Measures that force individuals to change their travel behaviour and preferred car choice, lead to welfare losses. Welfare losses can have a significant influence on the costs of CO_2 measures in transport. Although these welfare costs are difficult to quantify, ignoring them may result in a substantial underestimation of cost-effectiveness. This dilemma makes it very difficult to establish a fair burden sharing over sectors based on cost-effectiveness.

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Colophon

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Long term climate goals call for immediate investment in new transport technology

To meet long-term climate targets, developed countries should reduce greenhouse gas emission with 65 to 95% compared to 2000 levels. If the transport sector should match these reductions three crucial conditions need to be fulfilled: (1) substantial changes in travel behaviour, travel demand and public acceptance, (2) availability of zero-carbon or low-carbon fuels, (3) availability of advanced vehicle technology. The measures that are currently available for the period until 2020 do not have sufficient potential to meet the long-term climate targets. To meet the goals, there is a need for parallel investments in 'new' technologies (electricity, hydrogen) which, in the future, could be decarbonised to a large extent. Since these new technologies have long lead and implementation times, a policy strategy should be developed today, which ensures that experience is gained and cost reductions are induced. A similar conclusion can be drawn for the Dutch climate policy programme *Schoon en Zuinig*: Most transport measures in the Dutch policy programme that contribute substantially to the emission reduction target for 2020 create little incentive for the development of vehicle technology and low-carbon fuels, which are needed in the long term.

Netherlands Environmental Assessment Agency, July 2009